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REVIEWS OF RESEARCH IN SCIENCE EDUCATION

Willard J. Jacobson, Series Editor

A Digest of Investigations in the Teaching of Science in the Elementary and Secondary Schools
By Francis D. Curtis

Second Digest of Investigations in the Teaching of Science
By Francis D. Curtis

Third Digest of Investigations in the Teaching of Science
By Francis D. Curtis

Research in Science Education: 1938 through 1947
By Robert W. Boenig

Research in Science Education: 1948 through 1952
By J. Nathan Swift

Research in Science Education: 1953 through 1957
By Elizabeth Phelan Lawlor

Third Digest of Investigations in the Teaching of Science

Francis D. Curtis

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FOREWORD

Science education research is the systematic attempt to define and investigate problems involved in learning and instruction in science. It is desirable that this research be cumulative so that investigators build on the research of others. Hopefully, research will also influence practice. These digests are designed to serve as a guide to reports of science education research and to make the results of research more readily available.

For some time, the "Curtis Digests" have been known as the best guide to science education research for the periods that were surveyed. But these "Digests" have long been out of print and generally unavailable to people concerned with science education. The three volumes of the "Curtis Digests" are being reprinted as part of a six-volume series of Reviews of Research in Science Education.[1] In these volumes science education research through 1957 has been reviewed and analyzed. After 1957 the analyses have been carried out by other agencies.

In general in this series, studies in science education that were done in a scholarly manner and that have been

[1]The following volumes are all available from Teachers College Press, New York, New York: Francis D. Curtis, *A Digest of Investigations in the Teaching of Science* (To 1925); Francis D. Curtis, *Second Digest of Investigations in the Teaching of Science* (1925-1930); Francis D. Curtis, *Third Digest of Investigations in the Teaching of Science* (1931-1937); Robert W. Boenig, *Research in Science Education* (1938-1947); J. Nathan Swift, *Research in Science Education* (1948-1952); and Elizabeth Phelan Lawlor, *Research in Science Education* (1953-1957).

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of significance in the field were considered for inclusion. Except for the first volume by Curtis, other knowledgeable science educators have been called upon to help make judgments on which studies should be digested. In the last five volumes supplementary bibliographies are included; in the last three volumes the studies listed are annotated. The digests and bibliographies in these volumes provide the most comprehensive guide to science education research literature through 1957.

For science education researchers, these digests and bibliographies should be considered as guides to the literature. In the Curtis volumes some unpublished studies have been digested, and these volumes are now probably the only available sources for these studies. In the volumes by Boenig, Swift, and Lawlor, only published studies were considered. The science education researcher can use these volumes to locate pertinent research studies. It is hoped that these volumes will help science education researchers to build on the work of others.

For practitioners in the field of science teaching, the digests and annotations should be useful as they attempt to deal with problems intelligently. In many cases, the summaries of results will be of help as teachers and supervisors search for ways to resolve practical problems. At other times the digests and annotations will lead to new perspectives on problems. It is hoped that the digested reports in these volumes will help teachers, supervisors, laymen, and science educators to use and apply the fruits of science education research.

Willard J. Jacobson
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PREFACE

This is the third volume of a series the first of which was published in 1926. Together the three volumes present digests of studies which represent the entire period of published research in the teaching of science from its beginnings early in this century through the year 1937.

The content of Volume I was selected entirely by the author. This book was restricted to the learning and curricular investigations selected in accordance with the author's arbitrary definitions of a learning and a curricular study.[1] The content of the second volume, published in 1931, was selected by the members of the National Association for Research in Science Teaching, in the manner described in the Preface of that volume.[2] When it became evident from persistent inquiries from the field that there was a demand for a third volume of the series, the author decided to employ again in the selection of content essentially the same plan as that used in determining the studies to be included in Volume II.

In the fall of 1937, therefore, a letter was sent to every member of the National Association for Research in Science Teaching requesting him to return a list of bibliographical references of his own studies and of important studies made by other investigators, which had been published during the six-year period from 1931 to 1936, inclusive. A substantial number of titles was thus secured. This bibliography was supplemented with an extensive list of investigations in the teaching of science, which was compiled by twenty members of the author's Seminar in the Teaching of Science. It was

[1] *Investigations in the Teaching of Science*, Vol. I, pp. v–vi (Preface).

[2] *Investigations in the Teaching of Science*, Vol. II, pp. v–ix (Preface).

thought that the composite bibliography which included the numerous titles submitted by the members of the National Association for Research in Science Teaching and the bibliography compiled by the Seminar would contain most of the significant published studies in the field for the period between 1931 and 1936 inclusive.

This bibliography was sent in mimeographed form to the members of the National Association for Research in Science Teaching accompanied by the request that each member evaluate on the following basis, only those studies with which he was sufficiently familiar that he felt competent to evaluate them:

Write "2" in the left-hand margin opposite each title which you think should certainly be included in the forthcoming volume.

Write "1" opposite each title which you consider not of the first rank of investigations, but yet desirable for inclusion if space limitations permit.

Write "−1" opposite each title which you consider scarcely worthy of inclusion in a limited list of investigations.

Write "−2" opposite each title which for any reason you consider totally unworthy of inclusion in the forthcoming volume of investigations.

The respondents were requested to send additional bibliographical references of their own and other's studies, especially those published during 1937, since it had been decided to extend the scope of the present volume to include that year; and of older studies which they thought should have been included in the two preceding volumes of Digests. They were also asked to indicate by school and approximate title, worthy unpublished Doctor's dissertations.

Evaluated lists of studies were returned by forty-five members of the National Association for Research in Science Teaching.

A second bibliography was prepared which included the studies submitted by the members of the National Association for Research in Science Teaching for the year 1937, together with a supplementary bibliography for 1937 compiled by the students in the author's Seminar in the Teaching of Science.

A few studies published before 1931 and not included in the two preceding volumes of investigations were suggested by various members for inclusion in this third volume, and were therefore added to the second bibliography.

The second bibliography was submitted to the members of the National Association for Research in Science Teaching accompanied by the same instructions as accompanied the first. Thirty evaluations of this list were subsequently returned.

The content of this Third *Digest of Investigations in the Teaching of Science* was then selected from those studies which had received the highest evaluations as indicated by the algebraic sums of points assigned them by the evaluators. These sums for the studies on both bibliographies ranged from 64 to −18. Because only two-thirds as many evaluations of the second bibliography as of the first were submitted by members of the National Association for Research in Science Teaching, the algebraic sums representing the composite evaluations of studies in the second bibliography were multiplied by 1.5 in order to make them comparable with those of the first.

Because of space limitations the published studies included in this volume are those only which, in the first bibliography, had composite evaluations of at least 18 points, and those which, in the second, had composite evaluations of at least 12 points. It seemed desirable to include also digests of outstanding unpublished studies. There is an enormous number of unpublished Masters' theses, so many in fact that it seemed futile to attempt to include them. The author did, however, include digests of all the unpublished Dissertations which he was able to secure. It is encouraging to note, however, that few dissertations fail to be reported, at least in part, in the educational journals.

The organization of this volume follows the general plan of Volume II. The studies are for the most part grouped in

three fields, the elementary, the secondary, and the college field. In the first part of the secondary division, investigations applying to specific courses of science, as general science, biology, and the like, are placed together; in the latter part of this division the studies of more general application are presented. At the end of this section, are several groups of closely related studies not restricted to the secondary field, each of which deals with some special phase of science teaching as investigations of scientific attitudes, values of silent pictures and talking pictures, etc.

As in the preceding volume, additional references to published and unpublished investigations, the former taken chiefly from the composite bibliographies from which the studies presented in this book were selected, have been placed at the ends of various groups of related studies.

A few striking differences between the content of this volume and of the preceding two seem worthy of mention as indicative of trends in research in this field:

1. The greatly increased proportion of learning studies;
2. The marked progress in the improvement and refinement of statistical procedures;
3. The increased attention to problems dealing with the chief objectives of science teaching (scientific principles, scientific attitudes, and scientific method) as stated by the Thirty-first Yearbook Committee of the National Society for the Study of Education.
4. The increased proportion of investigations dealing with problems which are of general importance in the entire field of science teaching rather than of specific application to a single course.

It will be noted that the studies in this volume begin with No. 164 because the three volumes together constitute a continuous series.

As in the preceding volumes, the author has endeavored to report accurately the Problem, the Method, and the Findings

and Conclusions of each study as presented in the available report. He has made no attempt to supplement or interpret any of these reports. In the interests of accuracy and completeness, he has submitted the digests of all the Doctor's dissertations and of several of the other more elaborate and extensive studies, to their respective authors for criticism and approval.

This book together with the two preceding volumes is adapted as a textbook for teachers in universities, colleges, and normal schools—both those who are conducting advanced courses and seminars for the purpose of training graduate students to do research in the teaching of science, and also those conducting similar courses in other fields of education.

This book, like the preceding ones, should also serve a practical need as a source book and a reference book for:

1. All workers in educational research, particularly in the field of the teaching of science, who need to have readily available a list of important problems in educational research, together with a description of the techniques used in their solutions.

2. Administrators, supervisors of the teaching of science, and classroom teachers of science, who will find, especially among the Findings and Conclusions, much of practical help in the solutions of their immediate problems.

3. Curriculum committees concerned with the preparation of materials in the field of science.

As with the two preceding volumes, if the value of this book, as indicated by its reception, proves sufficient, it is the author's and the publisher's intention to issue a fourth volume a few years hence, bringing the presentation of important research work in this field of education again up to date.

FRANCIS D. CURTIS.

ANN ARBOR, MICHIGAN,
June, 1938.

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RESEARCH INVESTIGATIONS IN THE TEACHING OF SCIENCE

STUDY NO. 164

A Basis for the Selection of Course Content in Elementary Science

By Martin L. Robertson*

UNIT I

Problem.—To determine the important principles of science suitable as goals of instruction in the elementary grades.

Method.—The investigator first formulated criteria for selecting sources of principles. These criteria were as follows:

The study must have been undertaken with the purpose of selecting scientific principles

The available report must contain a more or less detailed list of the scientific principles which have been determined from the investigation

The report should indicate the rank order of the frequency of appearance, or in some manner should point out the stress given in the analyzed materials to each of the principles

Ten studies were found to meet these criteria. These studies

* Dissertation for the degree of Doctor of Philosophy, University of Michigan, 1934. The first unit of this study is briefly reported under the title, "The Selection of Science Principles Suitable as Goals of Instruction in Elementary Science," in *Science Education*, XIX (February and April, 1935), 1–4, 65–70; the third unit appears as "The Adequacy of a List of Principles to Satisfy the Interests of Children as Indicated by Questions," in *N.C.E.S. News Notes*, I (January and March, 1935), 29–36, 45 and 46.

included four unpublished master's theses[1,2,3,4] and another unpublished study from the University of Michigan,[5] three published studies by Downing,[6,7,8] and two unpublished studies from the University of Chicago.[9,10] Lists of major and minor principles were secured from these sources. The following criteria of a principle, established as the result of "many weeks of consideration" by a group of teachers of science enrolled in the Seminar in the Teaching of Science at the University of Michigan, governed the final selection of principles of science from the available lists:[11]

To be a principle, a statement must be a comprehensive generalization
It must be true without exception within the limitations specifically stated

[1] Earl Debus, Determination of the Principles of Chemistry. Master's Thesis (unpublished), University of Michigan, 1931.

[2] R. Adrin Kay, Determination of the Scientific Principles as Found in Six Widely Used Physics Texts. Master's Thesis (unpublished), University of Michigan, 1932.

[3] Fred Moore, Determination of the Principles of Chemistry. Master's Thesis (unpublished), University of Michigan, 1931.

[4] Oliver Blair Wilbur, A Study of the Principles of Science Contained in General-science Textbooks Published Since the Year 1924. Master's Thesis (unpublished), University of Michigan, 1931.

[5] R. C. Karpinski, Principles in Five College Textbooks in Geology. Unpublished Study, University of Michigan, 1933.

[6] Elliot R. Downing, *Investigations in the Teaching of Science*, Vol. II, pp. 72–79.

[7] *Ibid*, pp. 211–214.

[8] Elliot R. Downing, *A Program for Teaching Science*, Thirty-first Yearbook of the National Society for the Study of Education (Bloomington, Ill.: Public School Publishing Company, 1932), Chapter XIV.

[9] Jessie A. Menzies, *Investigations in the Teaching of Science*, Vol. II, pp. 380–384.

[10] John T. Sites, *Ibid*, pp. 269–276.

[11] Compare with Downing's definition of a principle, *Investigations in the Teaching of Science*, Vol. II, p. 74 (footnote), and with Pruitt's criteria of a generalization, p. 156, of this volume.

It must be a clear statement of a process or an interaction
It must be capable of illustration so as to gain conviction
It must not be a part of a larger principle
It must not be a definition
It must not deal with a specific substance or variety, or with a limited group of substances or species

The principles included in one of the sources were compared one by one with the criteria, by a jury consisting of the investigator and three other members of the Department of Science of the University of Michigan High School. Those statements which in the opinion of the jury satisfied all the criteria were retained; those which did not were rejected or, in a few cases, were reworded so as to conform to all the criteria. "Certain principles were so inclusive that the jury deemed it practical to retain some of the minor principles that contributed to them." Whenever the jury disagreed with respect to whether a statement was or was not a principle, the statement was retained with the accepted list for subsequent consideration.

As a means of removing questionable statements and refining the list as a whole, the co-operation of six members of various departments of science in the University of Michigan was secured. Of these specialists, two were zoologists, two were chemists, one a physicist, and one a geologist. Each of these men spent from one to 10 hours in discussing with the investigator whether these statements as written fitted the criteria. Each statement which in the opinion of any one of these subject-matter specialists was not true was discarded or it was reworded so as to make it a correct statement of a principle. In some cases principles which were suggested by one or more of the statements but which were not among those submitted for consideration, were stated correctly and in such a way as would satisfy all the criteria, by one or another of the subject-matter specialists, and were then

added to the list. The final list of principles and subsidiary principles numbered 243.

This list of principles was submitted to 20 supervisors and professors of the teaching of elementary science "who were actively engaged in teaching science in the elementary grades, supervising the teachers of science in those grades, or teaching teachers how to teach science in the elementary grades." These judges were asked to evaluate each principle on a five-point scale with respect to its appropriateness "as the ultimate goal or outcome of science in Grades I to VI inclusive"; the five points indicated respectively that in the judgment of the evaluator a principle was (1) "Not at all suited"; (2) "Poorly suited"; (3) "Neither well nor poorly suited"; (4) "Well suited"; (5) "Ideally suited as an ultimate goal of elementary science instruction in Grades I to VI inclusive."

Fifteen of the 20 judges returned evaluated lists. "Whenever the sum of half the ratings at (3), plus those at (4) and (5), amounted to 8.0 or more, the principle was deemed suitable for inclusion as one of the ultimate goals of instruction in elementary science."

Findings.—1. The final list of "defensibly stated principles and subsidiary principles appropriate to serve as ultimate goals of science teaching in the elementary school" numbered 113.

2. "In the pooled opinions of the 15 evaluators, many principles of science . . . are entirely unsuited as goals of instruction in the elementary school."

3. "There is a wide range of opinion among these elementary science experts with respect to the suitability of the various principles."

4. "There is a noticeable lack of uniformity among investigators with respect to the statement of principles."

The list of principles follows:

Principles of Science Selected by Fifteen Specialists in Elementary Science as Suitable for Goals in the Elementary School

All matter is composed of single elements or combinations of several elements and can be analyzed by chemical processes and divided into these units.

All substances are made up of small particles called molecules, which are alike in all samples of the same substance but are different in different substances.

The material forming one or more substances, without ceasing to exist, may be changed into one or more new and measurably different substances.

Elements or compounds may combine to form other substances.

Every pure sample of any substance, whether simple or compound, under the same conditions will show the same physical properties and the same chemical behavior.

No chemical change occurs without an accompanying energy change.

Things happen according to law; effect follows cause and to every action there is an equal and opposite reaction.

Matter and energy may be transformed but they cannot be created or destroyed.

The work obtained from a machine never exceeds the work put into it.

Certain energy forms travel in waves.

Waves travel in straight lines while passing through a uniform medium.

Light travels in straight lines in media of uniform density.

Radiant energy travels through space in all directions undiminished.

When waves strike an object, any one or more of these results will follow: they will be absorbed, they will be transmitted, or they will be reflected.

Ready absorbers of energy are ready radiators; slow absorbers are slow radiators.

Dark, rough, or unpolished surfaces absorb or radiate energy more rapidly than do light, smooth, or polished surfaces.

The darker the surface is, the better it absorbs light.

When light rays are absorbed, some of the light energy is transformed into heat energy.

Whenever an opaque object intercepts rays of radiant energy, a shadow is cast behind the object.

If a beam of light falls on an irregular surface, the rays of light are scattered in all directions.

An image appears to be as far back of a plane mirror as the object is in front of the mirror, and reversed.

When waves pass obliquely from one medium to a denser one, they are bent or refracted toward the normal; and when they pass obliquely from one medium to a rarer one they are bent away from the normal.

Light rays may nearly always be caused, by a convex lens, to converge, and often to focus; and by a concave lens, to diverge.

Ordinary light is made up of waves of many different wavelengths and each one is bent, or refracted, to a different degree, so that the various colors of which the light is composed are spread out in a band of colors known as the *spectrum*, the red being the least refracted, the violet the most.

The colors of objects depend on what light rays they transmit, absorb, or reflect.

Every portion of matter may change its state by absorbing or releasing energy.

The average speed of molecules increases with the temperature.

Compression of a confined gas increases its pressure.

Heat is liberated when a gas is compressed, and is absorbed when a gas expands.

Gases may be converted into liquids by reducing the speed of their molecules.

All gases must be cooled to, or below, a certain temperature in order to be liquefied.

When a liquid is changed to a gas, heat is absorbed; when a gas is condensed to a liquid, heat is liberated.

Gases expand when heated and contract when cooled, as do most liquids and solids.

Different parts of the same substance will expand by different amounts, according to the amount of temperature change produced.

A gas always tends to expand throughout the whole space available.

Pressure exerted by a confined gas always increases with the temperature and *vice versa*.

If the same pressure is maintained, the volume of a confined gas varies directly as the temperature.

The boiling point of any solution becomes lower as the pressure is decreased, and higher as the pressure is increased.

A body immersed or floating in a liquid is buoyed up by force equal to the weight of the fluid displaced.

Any substance that will dissolve in water will cause the resulting solution to boil at a higher temperature and to freeze at a lower temperature than that at which pure water boils or freezes.

Freezing point depression and boiling point elevation are proportional to the concentration of the solution.

The force of attraction or repulsion between two magnetic poles varies directly as the product of the pole strengths and inversely as the square of the distance between the poles.

Like magnetic poles always repel each other, and unlike magnetic poles always attract each other.

An electric current may be produced in three ways: by rubbing or friction, by chemical action, and by using magnets.

Like electrical charges repel and unlike electrical charges attract.

All materials offer some resistance to the flow of electric current, and that part of the electrical energy used in overcoming this resistance is transformed into heat energy which, when intense enough, produces light.

The amount of heat which a body acquires when its temperature rises a given amount is identical with the amount it gives off when its temperature falls by that amount.

As heat tends to diffuse and thus equalize temperatures of all places and objects with which it comes in contact, there is a continuous transfer of heat between bodies of different temperatures.

The rate of heat transference increases with the difference in temperature between the heated body and the receiving body.

The lower the temperature of a body, the less the amount of energy that it radiates; the higher the temperature, the greater is the amount of energy radiated.

The principal cause of wind and of weather change is the unequal heating of different portions of the earth's surface by the sun; thus, all winds are convection currents caused by unequal heating of different portions of the earth's atmosphere, and they blow from places of high atmospheric pressure to places of low atmospheric pressure.

Air has a tendency to move from a region of higher pressure to one of lower pressure; the greater the difference, the faster the movement.

In the Northern Hemisphere great volumes of air revolve in a counterclockwise direction, and in the Southern Hemisphere they revolve in a clockwise direction. Bodies of land heat up and cool off more rapidly and more readily than do bodies of water.

The more nearly vertical the rays of radiant energy, the greater is the number that will fall upon a given area, and the greater is the amount of energy that will be received by that area.

The atmosphere of the earth prevents the heat of the earth's surface from escaping, and the earth begins to cool only when the amount of heat lost during the night exceeds that gained during the day.

The higher the temperature of the air, the greater is the amount of moisture required to saturate it.

The pressure of air decreases with an increase in water vapor content, other conditions remaining unchanged.

The pull of gravity is proportional to the mass of the body and inversely proportional to the square of the distance between the center of mass of the body and that of the earth.

All bodies in our solar system are controlled by the gravitational attraction of the sun, about which they revolve in huge ellipses and in nearly the same plane.

Movements of air, water, and solids on the earth are due to gravity plus rotation of the earth.

Any body of liquid free to take its own position will seek a position in which all surfaces lie in the same horizontal plane.

A body at rest or in motion will remain at rest or continue in motion in a straight line until compelled by some force to change its condition of rest or motion.

A body in rotation tends to fly out in a straight line which is tangent to the arc of rotation.

The amount of momentum possessed by an object depends on its weight and its speed of motion.

Whenever one surface is moved over another surface there is always friction (resistance to motion) which always results in the transformation of some of the mechanical energy of the moving object into heat energy and in the wearing away of some of each surface.

Sound is produced by vibrating matter and is transmitted by matter.

The more rapid the vibrations of a body, the higher is the pitch of the note emitted by it.

The greater the space through which a body vibrates the louder is the sound it produces.

Musical tones are produced when a vibrating body sends out regular vibrations to the ear, while only noises are produced when the vibrating body sends out irregular vibrations to the ear.

The environment acts upon living things and living things act upon the environment.

The cell is the unit of structure and function in all organisms.

Food, oxygen, certain optimum conditions of temperature, moisture, and light are essential to the life of most living things.

Before the seed that is planted in the soil can germinate, three factors must be present: oxygen, water, and heat.

Circulation is carried on in all living organisms.

The more complex organisms have been derived by natural processes from simpler ones, these in turn from still simpler, and so down to the first living forms.

From the lower to the higher forms of life, there is an increasing complexity of structure and this is accompanied by a greater division of labor.

Life springs from life and is subject to the same cycle of life: birth, youth, and dissolution.

Species not fitted to the conditions about them will not thrive and finally will become extinct.

The transfer of micro-organisms from infected to noninfected individuals may be prevented by (a) destroying the organisms; (b) disinfecting the carriers; (c) destroying the carriers; (d) retarding the multiplication of infecting organisms through the introduction of conditions inimical to their life; (e) and establishing immunity in individuals subject to infection.

Certain bacteria escape adverse conditions by forming highly resistant spores which can survive the conditions.

The chief differences in the structures of organisms from the lowest to the highest forms are the resultants of the means adopted to perform certain functions under different exigencies imposed by the environment and the mode of life.

All living organisms have the common life processes—reproduction, growth, nutrition, excretion, respiration, and irritability.

The power of reproduction is one of the characteristics of plants and animals, but the modes of reproduction vary.

In most mammals the fertilized eggs are held within the body of the mother where they grow until the embryos develop and are ready to be born; the young after birth are nursed for a variable period of time on milk secreted by the mammary glands.

Pollen will germinate on the stigmas of flowers of the same kind as that on which it grew and in rare instances also on those of flowers which are nearly related to the kind on which it grew.

To meet certain conditions of the environment, or, in a struggle for existence, most plants and some animals have adopted both asexual and sexual reproduction.

The plants and animals in a given environment are mutually interdependent.

The oxygen of the atmosphere is removed by animals and replaced by green plants.

Since other organisms constitute an important part of the environment of every living thing it is true that there is a complex web of life, an interdependence of organisms producing a nice balance of nature.

Bacteria by means of enzymes which they produce cause chemical changes in the substances from which they secure their nutrition; thus fermentation, putrefaction, decomposition, and decay are largely the results of bacterial processes that restore to the atmosphere and the soil substances which plants and animals use in their vital processes.

Certain associations, i.e., commensalism, community or social life, and parasitism, are the result of a struggle for survival.

During all life processes there is a building up and a tearing down of protoplasm with constant transformation of energy.

The utilization of food in the body depends on the heat liberated by its oxidation.

Protoplasm may be nourished only by food substances which have been reduced to liquid form by enzymes.

In the presence of sunlight chloroplasts of green plants convert carbon dioxide and water into sugar and starch, and liberate oxygen, thus directly or indirectly producing practically all the food in the world.

The various kinds of food are used by the body in growing new cells, in rebuilding cells, in providing energy for the body activities, and in doing work.

All the higher forms of terrestrial life are dependent either directly or indirectly on the soil bacteria for their nitrogen intake.

Protoplasm is the one essential constituent of every living thing, upon the peculiar properties of which the life of the organism depends.

The energy which makes possible the activity of most living organisms came at first from the sun and was secured through oxidation of food within the organism.

The phenomena of life involve chemical change, so that wherever living processes are being carried on, chemical changes are taking place; however, chemical change may proceed without involving life.

Strata of rocks occur in the earth's surface in the order in which they were deposited, except in the case of overthrust faults.

The present is the key to the past.

The succession of fossils in the rocks shows a progressive series from simple to complex.

The conditions under which glaciers tend to form result from an increase in either latitude or altitude.

Streams have a regular cycle: youth, maturity, and old age.

Two groups of forces are constantly acting on the earth's surface, one building it up, the other tearing it down.

Every stream is a part of a large drainage system which is wearing down the land surface.

What water breaks down in one place, it builds up at another.

Falls or rapids in a streambed will be formed wherever the stream flows over a hard stratum to a softer one.

When elevations or depressions are created upon the surface of the earth, the elevations are attacked by the agents of erosion and the materials are carried to the depressions where sedimentary rocks are formed.

Deposition in the form of moraines is equal to the amount of the material which was removed by erosion. Erosion takes place in proportion to the resistance of the rocks to decomposition and disintegration.

UNIT II

Problem.—To obtain a list of subject-matter topics that are suitable to elementary science, and that can contribute to an understanding of scientific principles.

Method.[1]—The first step in the procedure was the selection of investigations the results of each of which presented "a more or less detailed list of science topics presumably suitable for Grades I to VI inclusive," which had been arrived at by a technique of research accepted "by a graduate committee of a reputable institution." Five studies satisfied these criteria.[2,3,4,5,6] "The findings of these five studies include

[1] Compare the technique employed in this unit with that described in *Investigations in the Teaching of Science*, Vol. II, pp. 92–96.

[2] Rose Lammel, Intermediate-grade Children's Concepts of Scientific Terms Found in Readers Used to Develop Skill in Reading. Master's Thesis (unpublished), Colorado State Teachers College, 1930.

[3] Lois Mathis, An Analysis of Recent Elementary Science Courses of Study. Master's Thesis (unpublished), University of Chicago, 1932.

[4] Eveus Newland, A Study of the Allusions to Science in Magazines. Master's Thesis (unpublished), Colorado State Teachers College, 1932. See this volume, pp. 232–234.

[5] Martin L. Robertson, A Synthesis and Evaluation of Subject-matter Topics in Elementary Science. Master's Thesis (unpublished), University of Michigan, 1931.

[6] Clem Thompson, An Analysis of Elementary Science Courses of Study. Master's Thesis (unpublished), University of Chicago, 1920.

data derived from thousands of children's questions, from analyses of nearly one hundred fifty courses of study, from extensive reviews of authoritative opinions of laymen, from the opinions of experts, and from an extensive study of the science magazines."

The second step involved the tabulation of the data from all these sources. Each principle was written on a large sheet of paper ruled in columns each of which was designated by the name of one of the source studies. "Each topic from the Robertson study . . . was written on the sheet containing the principles to which, in the investigator's judgment, it most directly contributed." The final relative value of each topic, as given in the Robertson study was written opposite the topic in the column marked "Robertson."

When all the topics in the Robertson study had thus been entered, the final relative values (rankings) of the topics in the Newland study which were common to both the Robertson and the Newland study were written opposite the respective topics, in the column marked "Newland." Additional topics found in the Newland study but not in the Robertson study were added under suitable principles, and their rankings were written opposite the topics in the "Newland" column. A similar procedure was followed with the topics in the Lammel, Thompson, and Mathis studies. The result was an outline containing as main topics all the principles determined in Unit I, and under these all the topics revealed by the five contributing studies, with the value of each topic in each study indicated. The five sources contributed to the outline 2,324 topics of which the following numbers were found in the respective sources: 1,039 (Robertson), 1,182 (Newland), 24 (Lammel), 252 (Thompson), and 398 (Mathis).

The composite outline, re-examined and checked by the investigator, was then submitted to four other teachers, all of whom were well trained in one or more branches of science and two of whom were actively engaged in teaching ele-

mentary science. These teachers met with the investigator and examined the outline critically to insure (1) that the position in the outline in which the investigator had fitted each topic was defensible; (2) that no topic appeared more than once unless it possessed more than one connotation which made necessary its allocation under two or more principles; and (3) "that no item worded differently, but apparently identical in meaning with another was left in the list."

The third step involved the determination of the rank of each item in each respective source in which it was found. The topics in each study were ranked in descending order, beginning with 2324, as determined by their final relative values in that study. Each item which did not appear in a given source was assigned the median rank of those ranks remaining unassigned after all the named topics in that source had been given ranks. ". . . each principle and major topic in each source was given the highest ranking assigned to any topic under it in the outline."

The fourth step involved the determination of the relative values or weights of the various contributing sources. Complete digests of the contributing sources, together with pertinent questions concerning the scope and validity of each, were sent to seven "qualified experts," who, together with the investigator, independently ranked all five studies, relatively, on the basis of 10 points for the Robertson study. The medians of these weightings were taken as the relative weights of the respective studies.

The fifth step was the determination of the relative values of each topic in each of the five sources. The relative value of a topic in a given source was found by "multiplying the rank of the topic by the weight assigned to the source by the eight evaluators."

The sixth step was the determination of the final aggregate value of each of the 2,324 topics. This value was obtained by adding the relative values of each topic in all five sources.

The last step involved the determination of the final relative values of all the topics. These values were obtained by reducing the aggregate values to percentages of the maximum possible value which any topic might have if it had the highest rank in every one of the five sources. Thus, the final relative value was found for each topic by dividing 100 times the final aggregate value of that topic by the product of the total number of topics (2,324) and the sum of all the assigned weights of the five respective sources.

Findings and Conclusions.—1. The 113 principles and the 2,324 topics of elementary science ranged in final relative values from 35.6 to 99.7 per cent.

TABLE LXXIX

THE VALUES OF THE PRINCIPLES AND THE SUBJECT-MATTER ELEMENTS BY SOURCES TOGETHER WITH THE AGGREGATE VALUES AND THE FINAL RELATIVE VALUES

Principles and topics	Sources					Final relative value†
	A*	B	C	D	E	
I. All matter is composed of single elements or combinations of several elements and can be analyzed by chemical processes and divided into these units	22,910	14,946	12,311	6,577	13,620	98.3
There are fewer than a hundred elements	21,110	14,813	6,097	3,109	5,781	70.0
Aluminum	6,430	14,813	6,097	3,109	5,781	50.6
Arsenic	6,430	9,262	6,097	3,109	5,781	42.9

* The letters A, B, C, D, E signify respectively the Robertson, Newland, Lammel, Thompson, and Mathis studies.

† The Final Relative Values are expressed in percentages of the highest possible value which a principle or a topic might have if it received the highest rank in every one of the five contributing sources.

2. "A large part of the subject-matter elements now available contribute to biological principles."

3. There are several principles of science rated by the 15 evaluators (see Unit I) as suitable content for courses in elementary science for which additional appropriate subject-matter elements should be developed.

4. "The biological principle, 'The more complex organisms have been derived by natural processes from simpler ones, these in turn from still simpler, and so down to the first living forms,' obtained the highest value in this list."

A sample of the data is presented in Table LXXIX.

UNIT III

Problem.—To determine the need for these principles of science in answering the questions of children.

Method.—The co-operation of grade teachers in 22 Michigan schools, of which 14 were in Flint, four in Ann Arbor, and four in Dearborn, was obtained. These teachers were asked to secure questions in three ways: (1) by recording all questions relating to science which the children happened to ask; (2) by asking the children of the fourth, fifth, and sixth grades to write on paper the questions relating to science which they wished answered; (3) by placing on the bulletin board a paper upon which the children were encouraged to write any questions relating to science, that they wished explained or discussed. A total of 6,429 questions was thus secured.

Each question, together with the grade, age, sex, and school of the writer was copied on a 3 × 5 card. "These cards were then grouped under the various branches of science, astronomy, biology, chemistry, etc. Then, within each group, the cards relating to the same topic, for example, fish, planets, stones, flowers, electricity, etc., were brought together. Next, the identical questions concerning each of these topics were separated out, counted, and attached together." Each

question was read and was discussed with "an experienced elementary school teacher who had science training," for the purpose of determining "the aspects of science . . . involved in the answer to the question."

All the questions were placed in one of three categories: (1) "those, the answering of which might be expected to lead to a comprehension of one of the principles in the list; (2) those, the answering of which might be expected to lead to a comprehension of a principle not in the final list of this study; and (3) those, the answers to which could not be interpreted to involve any principles of science." "In every case in which there was not entire agreement between the investigator and the elementary teacher as to which principle or principles the answer to the question might lead, the question

TABLE LXXX

THE NUMBER OF QUESTIONS RELATING TO EACH PRINCIPLE AND THE RANK OF EACH PRINCIPLE IN THE FINAL LIST ON THE BASIS OF THE NUMBER OF QUESTIONS, THE UNDERSTANDING OF WHICH CONTRIBUTED TO THE COMPREHENSION OF THE PRINCIPLE

Principles	Number of questions	Rank
I. All matter is composed of a single element or combinations of several elements and can be analyzed by chemical processes and divided into these units*	126	14
II. All substances are made up of small particles called molecules, which are alike in the same substance but different in other substances	10	59.5

was submitted to two other teachers of science for classification." "The question was then placed in a classification approved by all four judges." Since some of the questions were classified under more than one principle, 5,939 of the questions were given 6,772 allocations; 347 of the questions were classified as relating to no principles determined in Unit I; and the remaining 143, as relating to no principles of science.

The principles were tabulated, each with the number of questions asked about it and its rank as determined by this number of questions in relation to the total number of questions asked about all the principles.

Findings.—1. Ninety-three and two tenths per cent of all the questions related to principles determined in this study; 4.8 per cent related to no principles selected by the 15 judges (Unit I); and 2.0 per cent related to no scientific principles whatever.

2. "As a whole, more questions are asked concerning biological topics than physical."

A sample of the final table is presented in Table LXXX.

STUDY NO. 165

An Experimental Application of a Philosophy of Science Teaching in an Elementary School

By George W. Haupt*

UNIT I

Problem.—To determine the major issues in the teaching of elementary science and the "philosophies of science instruction for children."

Method.—An analysis was made of 10 books and nine articles dealing with the teaching of elementary science and nature study, for the purpose of determining the various conflicting issues. These issues were then analyzed in order to determine the philosophies underlying them.

* Dissertation for the degree of Doctor of Philosophy, Contributions to Education No. 633. New York: Bureau of Publications, Teachers College, Columbia University, 1935. This investigation is reported in a series of articles: "Generalizations in Elementary School Science," *School Science and Mathematics*, XXXIV (June, 1934), 574–577; "An Experimental Application of a Philosophy of Science Teaching in an Elementary School," *Science Education*, XVIII (December, 1934), 234–238; and "Grade Placement in Elementary School Science," *School Science and Mathematics*, XXXV (November, 1935), 858–864.

Findings.—1. The five issues revealed by the analysis are as follows:

Shall the aim of elementary science be of the "moral, vocational, aesthetic, civic, ethical, and spiritual" type with statements of goals of attainment such as "moral uprightness," "ability to discern the social obligations and individual rights of one's self and others," etc.; or shall it be of the "generalization," or "objective" type with statements of goals of attainment, such as "The universe including the earth is very old," "Space is vast," "Energy is not destroyed but is changed into other forms," etc.?

Shall the activities of observation, collecting, and identification be ends or means to explanations and interpretations?

Shall the science content for the elementary school be predominantly biological or shall it comprise content from all fields of science?

Shall or shall not personification and animism be used for motivation?

Shall grade placement be in terms of the special branches of science, biological for the lower grade levels and physical for the higher; or shall it be in terms of difficulty or complexity of content, irrespective of any special divisions of science?

2. The conflicting philosophies revealed by the discussions of these issues are as follows:

Experiences should be provided which permit of interpretation and explanation contributory to an understanding of "large generalizations," since children are capable of the kind of mental activity required by this type of aim.

Young people are not capable of the kind of mental activity necessitated by the "large generalizations" type of aim and therefore their experiences should consist mainly of observations.

UNIT II

Problems.—(1) "To select a major generalization[1] suitable as a basis for science instruction in the grades; and (2) to determine the elements of learning contributory to an understanding of the objective."

[1] In this study generalization is defined as "a process or thought movement" rather than "a statement of thought product."

Method.—A study of major objectives or "large generalizations" as determined by Craig[1] followed by a discussion of these objectives in the Seminar in Science Education in Teachers College, led to the selection of the objective having to do with the principle of conservation of energy. It was further decided to limit the study to an investigation of a special phase of this principle in accordance with these restrictions:

The specific manifestation of energy selected for instruction in the elementary school should be one inherent in an extensive range of energy transformations.

The specific manifestation of energy selected for instruction in the elementary school should touch, to as great an extent as possible, the experiences of children of Grades I to VI.

"Light was selected as presumably fulfilling these criteria most perfectly." Six books and two courses of study were then analyzed to obtain statements concerning light. These statements with their sources were written individually on cards.

Findings.—1. The analysis resulted in 319 separate statements concerning light. These appeared with a frequency of 513 times.

2. Of these statements, or elements, 63 appearing with a frequency of 92, referred to "Light in Its Relation to Energy, Its Transformations and Conservation."

3. Of these 63 elements, 39, appearing with a frequency of 54, concerned the "Light-Life" phase of the principle of conservation of energy, which is stated thus, "Green plants convert the energy of light into the energy of food and fuel."

UNIT III

Problem.—To determine some of the ideas held by children in the grades concerning the phenomena of light, as a basis for determining how well the "Light-Life" phase, tentatively

[1] *Investigations in the Teaching of Science*, Vol. II, pp. 44–47.

selected as the basis of further study, integrated with children's experiences.

Method.—"The following letter was distributed to elementary-school teachers and supervisors enrolled in the classes of the Department of Natural Sciences of Teachers College:"

To Co-operating Teachers and Principals:

We are making a study at the Horace Mann School of children's conceptions of the phenomena of LIGHT. You can help us by getting all of your children who write, from the first grade upward, to tell us all they can about light.

After placing the word LIGHT on the board, read or tell the following to the children: "Write, in the way you want to, all you can about light. All of you know many things about light. Write these down as you think of them. If you have any trouble with the spelling of a word, spell it the way it sounds to you. Put your name, grade, and age at the top of each paper."

Do not allow the children to ask questions aloud for they may give suggestions to others. Please be sure to put the name, grade, and age at the top of each paper.

Return papers as soon as convenient to

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Horace Mann School
Teachers College

"Sixty-eight of these student-teachers returned one or more sets of children's papers (a 'set' comprising the papers from one class of any of the six grade levels). In many cases in the lower grade levels, where the children could not write, the teachers wrote what the children told them. The total number of sets of papers returned was 162, the sets ranging from Grades I to IX inclusive."

"The statements from these children's papers were recorded and tabulated on cards . . ." An analysis was made to determine the statements found on 100 papers from each of Grades I to VII, inclusive.

Findings.—1. The analysis resulted in 641 distinct elements which appeared with a frequency of 4,003.

2. Of these, 150 elements, appearing with a frequency of 1,740, referred to "Light in Relation to Energy, Its Transformation and Conservation."

3. Of these 150 elements, 55, appearing with a frequency of 782, concerned the "Light-Life" phase of the principle of conservation of energy.

UNIT IV

Problem.—To determine whether there are characteristic differences in the kinds of statements which children of different grade levels make in regard to the "Light-Life" phase of the principle of conservation of energy.

Method.—A study was made of every statement pertinent to the "Light-Life" principle, among those found in the six hundred papers analyzed in Unit III. Characteristics which seemed typical of each grade were noted.

Findings.—1. "The differences between the statements made on the lower and higher levels are differences in concepts and in the association of concepts."

2. "The concepts needed for the associations made on the lower grade levels depend upon few experiences which are easily given or acquired."

3. "The concepts needed for the associations made on the higher grade levels depend upon series of experiences which must be related and held. These experiences are not so easily acquired or presented."

4. "More concepts are associated in the statements made on the higher grade levels."

UNIT V

Problem.—To determine the effect of instruction on the ideas concerning the "Light-Life" principle held by children before instruction, and the effectiveness of "instruction in imparting ideas which were not held before instruction."

Method.—Three sets of tests based on the statements secured from the two analyses (Units III and IV) pertaining to the "Light-Life" principle, were constructed. The first of these tests consisted of 29 statements in front of each of which the child was to write *S*, *D*, *X*, or *W*, to indicate respectively whether he was sure the statement was correct, doubtful of its correctness, entirely ignorant of the statement, or of the opinion that the statement was wrong. The second test consisted of having the children write all they could concerning the "Effect of Light on Plants," or "The Relation of Light to Plants." "These topics were written on the blackboard and oral instructions to 'write about the topics' were given." The third test consisted of 21 words and phrases pertinent to the "Light-Life" principle. The pupils were asked to write sentences so as to use as many of these words as they could. They were directed to use the words as many times as they liked in telling all they could about the relation of light to plant life.

These tests were administered in order, a week apart, as pre-instructional tests.

In assembling the data, "little weight was given to the results from the first test, . . . but statements were retained which appeared in the second test and not in the third, or in the third test and not in the second." Because the children of the three lowest grades could not express themselves adequately in writing, they were questioned orally and individually. During these pre-instructional conversations, "four persons were in the room: the child, the questioner, and two students from the Department of Natural Sciences of Teachers College who recorded the procedure verbatim. The presence and activities of these auditors were kept as inconspicuous as possible."

Material affording "an interpretation of certain learning experiences in terms of the objective, 'Green plants convert the energy of light into the energy of food and fuel,'" was

taught to a group of children in each of the Grades I to VI, inclusive, of the Horace Mann Elementary School. These groups numbered respectively 32, 40, 22, 37, 17, and 21 children. Their I.Q.'s ranged from 87 to 165; the median I.Q.'s of the groups were respectively 121.5, 116.5, 119, 115, 109, and 118.

With all six grades "a potted plant and a large crayon-colored picture of a green plant were used to show the main parts of a plant: root, stem, leaf, and flower. Experiments were then done by teacher and pupil to show that green plants turn toward the light; that green plants get yellow in the dark; that such yellow plants then become green again if placed in the light; and that green plants finally die if left for long in the dark." Additional instruction was given the various grades appropriate to their maturity and development.

"In the first three grades the lessons were 20 minutes in duration and were given once a week. In Grades IV, V, and VI the lessons were 30 minutes in duration and were given once a week." There were five lessons for first grade, six each for the second and third, nine for the fourth, four for the fifth, and 10 for the sixth.

With the upper three grades, the last two of the pre-instructional tests were administered following the instruction. With the three lower grades, the entire pre-instructional testing program was repeated.

The data from the pre-instructional and the post-instructional tests were organized in accordance with the following units, each of which implies a principle to be developed in the children's minds as a result of the teaching:

Necessities for Plant Growth and Life (exclusive of mention of Food and Fuel Making)

Effect of Light on Plants (exclusive of mention of Food and Fuel Making)

Interrelations of Plants and Animals (exclusive of mention of Oxygen and Carbon Dioxide Cycle)

Relation of Light to Animal Life (exclusive of mention of Plants as Intermediaries)

Comparison of Natural and Artificial Lights and Their Effects upon Plant Life

Food and Fuel Making by Plants—Where the Plants Get Food

Oxygen and Carbon Dioxide Cycle—The Balanced Aquarium

For each grade, counts were made of the numbers of different statements which were made before and after the instruction; the numbers of these statements which were correct; the numbers which were incompletely correct, equivocal, or vague; and the numbers which were entirely wrong. Also computations were made of the percentage of the class which made each statement.

Findings and Conclusions.[1]—1. The objective type of aim, as exemplified by a scientific principle such as that used with Unit V, "can be used to select elements of learning for presentation throughout a range of grade levels. All of these contributory elements may not be learned on every grade level but some of them will be learned on each grade level. The learning depends on the complexity of the elements. The complexity of the elements depends on (1) the number of concepts associated, and (2) the number and immediacy of the experiences which are involved in the concepts associated."

2. "The use of the objective type of aim does not necessitate its statement on every grade level. The same objective is, however, to be held by the teacher on all grade levels."

3. "When the objective type of aim is used, the 'same kind of learning' is not to be expected from the children of all grade levels. . . . The learning on both low and high grade levels, is . . . characterized by the association of ideas gained from experiences and in this there is no difference. But there is a difference in the complexity of the associations and

[1] Compare these conclusions with those of Croxton and Bedell, pp. 35–36 and 74, respectively, of this volume.

it is this difference which gives the key to a plan of rational gradation."

4. "The data indicate the presence of the same kind of mental activity on all of the grade levels studied. The grade differences are found in the complexity of the product of these mental activities."

5. "An 'understanding of an objective' is not approached or secured through repetition of the same or similar words of the objective but through the interpretations of numerous and varied learning experiences in such terms of the objective as are possible with the particular grade level."

STUDY NO. 166

A Technique for Appraising Certain Observable Behavior in Science in Elementary Schools

By Joe Young West*

UNIT I

Problem.—To devise a technique by means of which to secure objective data from controlled observations of pupils.

Method.—Following a survey of methods of appraisal of instruction used in elementary-school work, a special study was made of the controlled observation technique as a basis for a preliminary experiment with this technique. Grades III and V, enrolling respectively 30 and 32 children in School A, and Grade VI, enrolling 51 children in School B, were chosen for study. These schools were "widely divergent as to objectives and methods." For each grade a code of behavior responses in tentative form was made by determining the types of behavior which might be expected to result from work in the science classes so conducted as to realize the

*Dissertation for the degree of Doctor of Philosophy, Contributions to Education, No. 728. New York: Bureau of Publications, Teachers College, Columbia University, 1937.

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objectives of elementary science, selected in accordance with the criteria developed by Craig.[1] "The preliminary development of codes for School A was checked with the originators of the science program for this school, with the classroom teachers, and with science consultants. Additions and eliminations of code-item categories (e.g., inquiry, critical-mindedness, open-mindedness, generalizing, etc.) were made in the light of suggestions from these persons."

The code-item categories were arranged in two groups, *dynamic factors*[2] and *performance factors*. Each item of these codes was illustrated by means of examples secured from visits by "observing and taking notes of children's reactions to the teaching" and "formulated for guiding the investigator in making distinctions between the various items of the codes."

A sample of the code, constructed for the *dynamic factors*, follows:

CODE I—SCHOOL A

Directions for use: This code is to be used when the class is planning, reporting, discussing, demonstrating, experimenting, explaining, or constructing in connection with problems or activities which enter into their ordinary working program in science. Observe the group for the entire period, making accurate records according to the code numbers below for each individual. Enter the following codes upon the Tabulation Sheets:

Inquiry.....Ia

Enter the code number Ia against the name of each pupil for evidence of any kind of overt behavior which indicates that the pupil is using inquiry as a means of gaining information or ideas pertinent to science work, including sensitive curiosity. Examples are: Pupils asking *what* is the cause of a certain happening; *why* certain procedures were undertaken; *why* an experiment did not work; *how* to read a barometer; pupils asking questions which

[1] *Investigations in the Teaching of Science*, Vol. II, p. 42.

[2] "Dynamic factors include desires, attitudes, motives, opinions, and other similar features, while performance factors include participation in class work, responsibility of the individual for doing his share of the class work, and other similar types of behavior."

show thoughtful attitude as opposed to questions which show little or no thinking.

Critical-mindedness.....Ib

Enter the code number Ib against the name of each pupil for evidences of critical-mindedness toward the class situation as shown by weighing evidence with respect to its pertinence, soundness, and adequacy. Examples are: Pupil asking for statement of source of information before accepting it; pupil verifying statements read or heard; pupil questioning authority constructively; pupil questioning truth of a statement before he is willing to accept it as final.

The remaining sections of Code I for School A, similarly organized, related to the following categories: open-mindedness, generalizing, scientific problem-attack, recognition of achievements of thinking; recognition of interpretations of natural phenomena, and cause and effect relationships.

Similarly, Code II was constructed for the *performance factors* which included these categories: responsibility, voluntary activity, initiative, application of experience, self-appraisal, resourcefulness, skills, special abilities, work habits, and miscellaneous.

A *Tabulation Sheet* was devised for each code. This sheet provided spaces in which to record "the kind of class activity undertaken during each five-minute interval, the names of the children and their individual reactions to each situation and activity.

The investigator and an observer (a different one for each grade) who acted as a checker, recorded independently their observations of a lesson in science for each of the two grades of School A. No previous instruction was given either checker other than a careful reading of the codes and an explanation of the use of the tabulation sheets. The percentages of agreement of each pair of observations were computed for the various categories for each code. These percentages indicated a high degree of reliability, but in order to insure a more statistically reliable check, the coefficient of

contingency[1] between each observer and the investigator was calculated by Pearson's method. The codes were modified somewhat in the light of the experiences gained from these uses of them.

"The examples under each code were made into matching tests by arranging the examples in random order and having impartial persons match them according to the code item which they seemed to fit." To eliminate the possibility that any single code-item category was not reliable, an item-for-item check was made from the results of the matching tests given to members of the Course of Special Problems in Science Teaching at Teachers College, Columbia University.

Codes were made and tested for the sixth grade in School B, by a similar technique except that reliability was determined by comparing the markings made independently by the investigator and each of two markers during an entire class period.

Findings.—The results of this investigation indicated that "observation is an instrument of value in appraising certain activities in the educative process," and that, therefore, the codes were worthy of continued use in classroom situations in the three classes under observation.

UNIT II

Problem.—To apply the code in a long series of observations, in order to determine its worth as a means of evaluating various phases of the instructional situation.

Method.—Records of observation of both Grades III and V in School A were obtained by the investigator using the codes during 25 successive class periods, a total of 750 minutes of class work in each grade; and also similar records of 25 observations of Grade VI, School B, a total of 690 minutes of class work, were secured by him using a new code. With each

[1] Henry E. Garrett, *Statistics in Psychology and Education* (New York: Longmans, Green and Company, Inc., 1926), 195–203.

grade three analyses were made: (1) analyses "in terms of selected individuals to determine how often the classroom situation stimulated responses to the code items which were derived from the objectives for this science program"; (2) "analyses of behavior in terms of the group as a whole . . . in an attempt to give as complete a picture as possible of the classroom behavior in science"; and (3) "analyses in terms of the use of results by the classroom teacher . . ." Stenographic records were made of the classroom procedures of Grade III, School A, and of Grade VI, School B.

The statistical computations for each grade included the median number of responses and the per cent of responses to each code category. A study was also made of the number of minutes devoted to each of 11 kinds of activity (as cooperative work planning, reading and use of references, directed demonstration, and the like) and the per cent of total time devoted by the children of each of the three grades under observation to each kind of activity.

The means and S.D.'s of the frequency of observation of certain traits were computed for Grades III and V of School A, as a means of determining "the extent to which observations over five-day periods tend to represent results of observations over a longer period."

Findings and Implications.—1. "The controlled observation technique provides teachers, supervisors, other administrators, curriculum workers, and persons engaged in making school surveys with a direct method of making appraisals of classroom behavior of children in science . . . However, such appraisals supplement, but do not attempt to replace, other methods of appraisal in common use in schoolrooms."

2. To use effectively the controlled observation technique, the observer must possess "efficient sense organs"; "he must train himself to focus his attention upon his subjects in the midst of distracting conditions"; "he must have the ability to make accurate discrimination between code items"; "he

must understand the situation in which he is to work"; and "he must approach his observations with an open mind."

3. "Data obtained by the controlled observation technique provide a more objective record of classroom behavior than the teacher's impressions of the group. Such data may be used to characterize individual children in terms of the number and variety of the responses. Children not participating may be detected and others failing to make certain types of desired responses may be recognized."

4. "Quantity of responses should not be interpreted as reflecting quality. Quality of responses can be judged by examination of stenographic records of children's responses which are listed during observations of classroom behavior."

5. "Relation of specific data can be made to problems of individual adjustment. The controlled observation technique seems to give a more accurate record of group behavior than of individual behavior. . . . the larger the group the fewer are the opportunities for individual participation, and as a result individual records become less accurate."

6. "Comparison of individual records with the record of the group provides a partial means of showing the interaction of the group and the individual . . ."

7. The technique may be made the basis for modifying and evaluating specific methods, classroom procedures, and curricular materials, and for re-evaluating objectives.

8. "Findings of this study would indicate that the larger objectives of science teaching as listed in the Thirty-first Yearbook of the National Society for the Study of Education[1] can be used for guidance by teachers of science in elementary schools."

9. Results of this study show that children recognize important elements of the scientific method.

[1] *A Program for Teaching Science*, Thirty-first Yearbook of the National Society for the Study of Education, Part I (Bloomington, Illinois: Public School Publishing Co., 1932), p. 52.

10. Observations over a five-day period indicate with sufficient accuracy the tendencies toward specific behavior which may be expected to be revealed by similar observations over a 25-day period.

STUDY NO. 167

Pupils' Ability to Generalize

By W. C. Croxton*

Problem.—To determine "whether children of the various grades of the elementary school are able to generalize readily without explanation by the teacher."

Method.—This investigation consisted of five separate experiments. The first and second, carried on in 1928, involved the children of all the grades from the kindergarten through the eighth in the Riverview School of the State Teachers College, St. Cloud, Minnesota. The remaining three experiments, carried on in 1936, involved children of all the grades from the kindergarten through the ninth, and in addition children of low I.Q. in two opportunity rooms, in the Riverview School and in two of the elementary schools of the city. A total of nearly two thousand children took part in the five experiments.

The techniques followed in Experiments I and III are given here as examples:

In the first experiment live animals (guinea pig, salamander, fish, canary, toad, water beetle) were placed on one end of a table. Potted plants (cactus, Jerusalem cherry in fruit, narcissus in bloom, cyclamen in bloom, coleus with variegated foliage, palm) were placed at the other end of the table. The pupils in each room gathered about the table. The experimenter designated the two groups as animals and plants, naming each animal and plant. The pupils repeated the names and were left free to observe and play with the plants and animals during the experience period. They were then asked to state as many ways as possible in which all of the animals on the table were different from all of the plants.

* *School Science and Mathematics*, XXXVI (June, 1936), 627–634.

The third experiment was designed to test the ability to formulate and apply the generalization that warm air rises and cold air sinks. The experimenter first called attention to the fact that by watching the direction taken by smoke issuing from chimneys, one can tell which way the air is moving. He then exhibited a bee-smoker, stating that the smoke would enable the pupils to follow the air movements. Children then came up to examine apparatus consisting of a kerosene lamp and a stack of tin cans filled with ice. They felt the cold cans and held their hands over the lighted lamp. Long cylindrical shades of tag board were then placed about the lamp and the stack of cans, and supported on wire frames. Smoke was then puffed in through a small hole in each shade. The pupils watched it issue forth. Smoke was also puffed against the heated radiators and the cold windows. These processes were repeated several times during the experience period. The generalization question was then asked, "What does this show about warm air and about cold air?" To test the application of the generalization pupils were then asked, "Does this mean that the air is warmest in this room near the floor, near the ceiling, or at about the height of your head?"

The other three experiments involved respectively observations of pendulums and their motions; observations of teeters and the ways in which they might be balanced with four boys of different weights; and observations of various groups of animals to determine how one group might be distinguished from another.

The total time spent by the investigator in each room was 15 minutes, eight of which were devoted to "exposure or directed play, and seven to recording the reactions. Occasionally in the lower grades it was necessary to extend the recording time slightly." The experiments were all carried on by the investigator, with the help of room teachers and student teachers. "In the kindergarten and first two grades the children reported to recorders stationed about the room. Children above these grades wrote their generalizations and answers to application questions." "No explanations, discussions, or individual aid was given."

In the first experiment, the average number of generalizations per pupil was determined. In the last four experiments,

the percentages of pupils who were able to generalize, the percentages of those who were able to apply the generalizations, and the percentages of those who were able both to generalize and to apply the generalizations were determined.

Findings.—1. With Unit I Experiment I, "intelligent generalizations were formulated in all grades," though "generalization in the kindergarten dealt only with movement and color." "The range as well as the number of generalizations tended to increase throughout the grades," from an average number of .31 in the kindergarten to 4.00 in the eighth grade.

2. The summary of Experiments II to V inclusive, shows that the range in percentages of pupils of the various grades who were able to apply generalizations was from 14 for the kindergarten to 66 for Grade IX, with all but the kindergarten, Grades I and II, and the first opportunity room above 40 per cent.

3. The summary of Experiments II to V shows that the range in percentages of pupils of the various grades who were able both to generalize and to apply, was from five for Grade I to 55 for Grade VIII, with only the Grades VI, VII, VIII, and IX, and Opportunity Room II above 40 per cent.

4. In general it was found that the ability to generalize, to apply generalizations, and to do both increased with the grade.

"Tentative Conclusions."[1]—1. "These data indicate that many children in the higher primary, the intermediate, and the junior-high-school grades are capable of generalizing."

2. "While the experiments do not prove that most pupils in the kindergarten and lower primary grades could not generalize if a more adequate experience basis were provided, the data, together with the evident obsession manifested by these children for obtaining emotional satisfaction, do suggest that early childhood is pre-eminently a period for satisfying interactions."

[1] Compare these conclusions with those of Haupt and Bedell, pp. 26–27 and 74, respectively of this volume.

3. "There is little in these experiments to indicate that junior-high-school pupils possess markedly superior ability to generalize than intermediate-grade pupils possess, the difference in scores in favor of the former being little more than might reasonably be credited to added experience. The fact that this superiority manifested itself in more consistently applying their generalization, leaves this matter in doubt, however."

4. "The scores of the pupils in the opportunity rooms indicate that other reasons than subnormal ability to generalize enter into their classification. It will be noted that the scores of the children in Opportunity Room I, most of whom are rated below I.Q. 70, are about equal to those of children in the second grade. On the other hand, the scores of pupils in Opportunity Room II compare rather favorably with those of junior-high-school pupils. However, the numbers involved are too small to make the findings of special significance."

STUDY NO. 168

A Comparative Study of the Efficiency of Dramatic and Non-dramatic Methods in Teaching Science to Fifth-grade Children

By Robert Alonzo Greene*

Problem.—To determine "the effectiveness of the use of classroom plays as a teaching method."

Method.—This investigation employed two types of play construction, the "teacher-written" type, in which the children are given "a ready-made play, with the plot, speeches, and stage directions all completely worked out"; and a "pupil-written" type which supplies "a group of characters, a plot outline and the first part of the play worked out with speeches

* Unpublished dissertation for the degree of Doctor of Philosophy, Cornell University, 1937.

and directions," but which requires "the speeches and business to be developed by the children themselves in their own words and manner."

The factual material to be taught was divided into six units, each of which was developed into both a dramatic and a non-dramatic lesson. These units were based respectively on *The Habits of Moths and Butterflies; The Habits of Honeybees; The Economy and Conservation of Woody Plants; The Ecology of Domestic Mammals; The Physiology, Structure and Habits of Birds;* and *Superstitions Concerning Certain Small Garden Animals.* A play was written for each unit; four were written by teachers and two were left with the body in outline form to be written by the children. "Two of the plays were primarily intended for marionettes, two for pupil actors alone, and two included both marionettes and pupil actors." Each play was based on an outline in which "were concealed at least thirty items of fact" which furnished a basis for subsequent testing.

A total of 405 fifth-grade pupils under 40 teachers, participated in all parts of this investigation. These children were divided into six groups "as nearly equal in size as geography and their own choice of lesson types would permit." The six groups were then divided into three pairs of groups, to each of which would later be assigned two of the units, one a dramatic lesson and the other a non-dramatic lesson, both covering the same subject matter. The numbers of pupils from the various schools who participated in the different phases of the study varied from two to 40. The children were unselected, and, "since all types of schools were represented, would constitute a fair sample of average fifth-grade boys and girls" of New York State.

At the beginning of the experiment, "Each pupil was given the two objective tests on the subject matter of the two units with which he would later be dealing." Each teacher taught the non-dramatic lesson first to her group, again administered

the test covering it, then taught the dramatic unit and administered the second test. In the non-dramatic unit, the "method of presentation was restricted only in that it might not be dramatic, and the conventional class assignment, preparation and recitation by the question and answer method was the form most used." Each teacher "had been supplied with a comprehensive subject-matter sheet for each type of lesson, and, for the dramatic type, all the necessary materials for the construction and production of the play, including play manuscripts, direction sheets for construction, costuming, scenery, et cetera. After a general class discussion and a distribution of the jobs involved, the children then set to work on the play, making whatever studies of materials and sources seemed necessary to the group, creating the accessory properties and costumes and holding rehearsals."

Each teacher recorded the test results and also her opinion concerning the "interest and correlations, specific gains other than in science, changes in pupil attitudes," and "her personal opinion as to the value of the dramatic form of subject-matter presentation, based on her recent experience."

The results from the objective data were judged on the basis of average gains of the pupils in the two groups. Similarly computations were made of the average number of minutes to gain one point by each method, and "the average number of factual points gained in each hour of time spent by the children of each school on each of the six different units." Comparisons were made both with respect to the three play types (marionettes, marionettes with pupils, and children alone); and with respect to teacher-written and pupil-written plays.

A further study was made of the numbers of pupils in each school who participated in various "co-ordinating activities"; of the extent to which these units were correlated with other school subjects; and of the improvement with respect to knowledges, skills, and attitudes in other subjects as a result of these science activities.

Findings and Conclusions.—1. ". . . children learn factual information only slightly, if any, more rapidly when taught by the dramatic rather than by the non-dramatic method."

2. "The dramatic method demands the expenditure of so much more time and energy and effort than does the non-dramatic that, if we teach purely to impart factual information, the dramatic method would be far too expensive to employ. In factual knowledge gained in this experiment the dramatic method was only about one-sixth as efficient as the non-dramatic method."

3. "The use of marionettes, either alone or with child-actors, effected a considerable gain in the measurable factual learnings. In the less-easily measured fields there seemed to be a corresponding benefit by the use of these devices in contrast to the conventional child-acted play."

4. "A sizable increase in factual learnings was observed from the use of plays partly written by the children themselves in contrast with the conventional adult-written play. Similar gains resulting from the interests, initiative and background studies necessary for this authorship were evidenced in many fields other than factual knowledge."

5. Children "are much more interested in the average dramatic lesson than in the non-dramatic presentation" and "feel well repaid for their extra time and energy spent."

6. The following "desirable and co-ordinated learnings" were developed more strongly by the dramatic method "especially where marionettes were employed": speech arts; character interpretation; bodily poise; fine and manual arts, including creative construction in many materials; group organization; social interplay and teamwork leading to performance.

7. "Co-operating teachers report far greater possibilities of correlating a topic lesson with the other subject matter of the school when the dramatic method is employed."

8. "The improvement of certain desirable traits and attitudes specifically observed here, such as co-operation, responsibility and leadership, appear to have been much greater through the use of the dramatic than the non-dramatic lesson form."

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[1] In accordance with the criterion repeatedly stated and indicated by members of the N.A.R.S.T. in connection with their evaluations of the studies presented in this book, no title is included in this bibliography as a report of a research investigation unless it presents a statistical treatment of data obtained in an attempt to solve by investigational techniques, a clearly stated or indicated problem.

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STUDY NO. 169

An Analytical Study of Attainment of Specific Learning Products in Elementary Science

By Wilbur Lee Beauchamp*

UNIT I

Problem.—To determine the extent and nature of the individual differences which arise in attaining specific learning products in elementary science.

Method.—This investigation was conducted with 21 unselected pupils in a sub-Freshman class in the University of Chicago High School. At the beginning of the experiment a battery of tests was given which included the Stanford Revision of the Binet-Simon Test; the Thorndike-McCall Reading Test; the Van Wagenen Reading Scale in Science; a pre-test of the best-answer type, constructed by the investigator to measure experiential background; and eight records of 20 minutes each for every pupil, with the Chicago Sustained Application Profile. The results of these tests showed that the pupils were superior both in intelligence and in rate and comprehension of reading; that before the experimental work was begun there were wide individual differences in the experiential backgrounds not only of the various pupils in any given unit but also of a given pupil in the different units; and that there were "marked individual differences and variations in the percentage and quality of application."

The investigation was carried on during four 50-minute periods per week from October 1 to May 15. During this time four units were studied, *The Earth on Which We Live*, *Weather and Climate*, *Food*, and *Our Water Supply*. The materials of instruction for these units were secured from text-

* Unpublished dissertation, for the degree of Doctor of Philosophy, University of Chicago, 1930.

books, reference books, field trips, experiments, oral presentations by the teacher, lantern slides, drawings, newspapers, and government bulletins.

The class was taught by its regular teacher, though the investigator was present at every class meeting. The teaching procedure followed the five steps outlined by Morrison,[1] namely, Exploration, Presentation, Assimilation, Organization, and Recitation. Problems, subdivided into a series of exercises, were set for the pupils to solve individually during the assimilation period. The investigation was chiefly concerned with the "differences in time and the number of trials required to attain the prescribed learning products," though other aspects of individual differences were also studied.

In order to establish a control of the time factor, the pupils were required to do all their work during the class period; no homework was assigned. The pupils were told to read through each problem and then to perform the exercises prescribed for it. They worked under the direct supervision of the instructor and the investigator who took special care to insure that the pupils did not receive help. Observation was made of the habits and methods employed by the pupils in meeting the situations presented to them.

Each pupil worked at his own rate through the assimilation period. Such additional work as he might do after completing the required problems of the exercise, and while awaiting the completion of time assigned to that unit, was not considered in this experiment. All papers were collected at the end of each period and were returned to the pupils during the next class period. Absences were taken into account in the various units in which they occurred.

Each solution was checked for correctness against a solution of the problem by the investigator, and if incorrect, was returned to the pupil for correction. "No differentiation for

[1] Henry C. Morrison, *The Practice of Teaching in the Secondary School* (Chicago: University of Chicago Press, 1926), Chapter XI.

degrees of understanding was made; credit for a solution was given only when a problem was satisfactorily solved." Thus the "number of trials or attempts necessary to attain the specific understanding" was determined. A record was kept, also, of the day on which each exercise in each problem was completed, and of the total time required to complete each exercise. These data permitted the determination of individual differences and variations in the rate of work.

The written reports of the solutions were analyzed for characteristic errors and for the nature of the difficulties encountered.

Findings.—As the pupils progressed through the units, individual differences were found to develop with respect to attitudes toward work and methods of study; the time required to attain the specific learning products; the number of trials required to solve the exercises; the interpretation of the exercises presented for solution; the types of errors made and the causes of these errors; and the ability to perform the different activities required in the study of science.

UNIT II

Problem.—To determine the factors which influence the progress of pupils in the attainment of specific learning products.

Method.—A comparison was made of the records of the experimental class (A) with those of a class (B), which the investigator had himself taught the preceding year by the same method and with practically identical units. Especial attention was paid to the time required for the completion of the same units by these two classes under different instructors who used somewhat different teaching techniques.

An analysis of the causes for slow or unsatisfactory pupil work in Class A led the investigator to alter his method of instruction (1) by carefully formulating the ideas to be attained by the pupils in the unit; (2) by constructing a series of exer-

cises directly focused upon these ideas; and (3) by setting up definite standards for the work of each period. He then compared the results secured by the original method used with Class A, with those obtained with a Class C in which the new methods were employed. He also compared the number of attempts required in completing various units by Classes A, B, and C.

Findings and Conclusions.—1. "The teacher has little if any effect upon the total time and number of attempts, or upon the extent of the individual differences and individual variations in completing the exercises."

2. "The technique of instruction exerts a greater influence upon the total time required to complete the exercises than do the individual differences in the pupils themselves."

3. "The technique of instruction influences to a small degree the variability in the amount of time required to complete the unit."

4. "The technique of instruction has little if any effect upon the individual variations in the time required for completing the exercises of the different units."

5. "The technique of instruction exerts a slight influence upon the total number of attempts required."

6. "The technique of instruction has little if any effect upon the individual differences and variations in the number of attempts required to solve the exercises."

UNIT III

Problem.—To determine the effect of instruction upon learning to make comparisons.

Method.—Two classes were used in this unit. One class, the control group, was given no instructions; the other, the experimental group, was given specific instructions on two separate occasions, the first time by means of detailed mimeographed directions of the steps to be followed; and the second time by means of individual conferences of the teacher with

the pupils as the latter worked at making comparisons. The same test was subsequently administered to both groups.

Findings and Conclusions.—1. Instruction in how to make comparisons "results in a method of response which is different from that obtained when no instruction in given."

2. Instruction in how to make comparisons "increases the ability of the pupil to find likenesses and differences in the data given."

General Conclusions.—1. ". . . while progress in the study of science is definitely related to such factors as intelligence, ability to read, experiential background, and sustained application, there are so many exceptions to this general relationship that the results are of little value in interpreting individual progress unless accompanied by observations of the pupil's method of work."

2. ". . . the learning situation is extremely complex . . . There is a constant shifting of attitudes and methods of work and . . . each exercise is qualitatively different for each pupil in the class. The interaction of these variable factors with other variables results in a change in the total situation which again reacts to influence the behaviour of the pupil in a given situation. The result is a learning situation that is in a state of constant flux. It is thus practically impossible to isolate one factor and definitely determine its causal effect."

3. ". . . there are many kinds of activities employed in the study of science and . . . the ability to carry on these activities is specific rather than general."

4. Most of "the individual variations which cause slow progress are corrective in nature. This is particularly true of application, attitudes toward study, and methods of study."

5. ". . . individual differences and variations in the pupil are more closely related to progress than is the method of instruction employed."

6. ". . . direct instruction in a method of study results in an increase in the ability to do that type of study."

7. "Pupils need to be made conscious of the types of study employed in science. . . . Pupils need to be taught how to solve the various kinds of problems, how to observe demonstrations, how to make analytical drawings, etc."

8. ". . . pupils need to be made conscious of their abilities and limitations."

9. ". . . the study of science must inculcate the methods of thinking employed by the scientist in the solution of problems. Subject matter alone will not produce the desired learning products. The crucial point in the teaching of science is the method employed by the teacher."

STUDY NO. 170

Methods of Determining Types of Content for a Course of Study for Eighth-grade Science in the High Schools of the Southern Appalachian Region[1]

By Feaster Wolford*

UNIT I

Problem.—To determine the objectives of education in general, and of courses of general science in particular.

Method.—An extensive analysis was made of articles and sections of books dealing with the objectives of education and of general science, to determine the nature of these objectives and the extent to which the objectives of education and of general science agree.

Conclusions.—1. "Educators seem universally agreed . . . that the objectives of education should be based upon an analysis of the activities of life, but there is a difference of

[1] The Southern Appalachian Region includes Alabama, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia.

* Unpublished dissertation for the degree of Doctor of Philosophy, Cornell University, 1935.

opinion as to what to include in the analysis. Most educators would use as a basis the things individuals do, but some would have as a basis what individuals should do in a well-ordered society."

2. "Several authorities seem to emphasize the utilitarian value of education by emphasizing the development of knowledges and skills in order to perform the activities met in everyday life. Others emphasize the importance of developing the personality of the individual through the creating of proper attitudes, habits, interests, standards, and ideals."

3. "There is no general agreement as to the character of objectives for science in the junior high school, but most authorities emphasize the ideas of exploration, stimulation, guidance, and adjustment to the environment. There appears to be no conclusive method of evaluating objectives, . . . "

4. "In courses of study the specific objectives for science are not always in harmony with the general objectives."

UNIT II

Problems.—(1) To determine the extent to which the subject matter in the science textbooks now used in the various states of the Southern Appalachian Region is applicable and adapted to the pupils in the high schools of the region; and (2) to study the organization of material in these books in order to classify under appropriate headings the material secured in the study.

Method.—An analysis was made of 10 textbooks of general science to note the extent to which their authors agree on what is essential in a general-science course. The results of this analysis were compared with those of similar analyses. A further analysis was then made of eight other general-science texts, none of which was more than six years old, in order to "find both the content and the organization of subject matter." The amount of space devoted to each subject-

matter unit and to each "activity situation" was determined in square inches of space in the books, and the average space devoted to each was computed.

Findings.—1. ". . . there is very little agreement among writers as to what should be included [in a textbook of general science], and . . . no attempt has been made to prepare a textbook that is specially adapted to a particular region."

UNIT III

Problem.—To determine the nature of state courses of study in general science.

Method.—All the courses of study for those states of the Southern Appalachian Region which included in their courses materials concerning science, namely North Carolina, South Carolina, Virginia, and West Virginia, were compared with the courses of study for Missouri, Texas, Montana, New Mexico, New York, New Jersey, North Dakota, and Iowa; and also with those for the city schools of Denver, Saint Louis, Baltimore, Detroit, and Philadelphia.

Findings.—1. "The courses of study for the region included are the results of the opinions of high-school teachers, state school administrators, and college professors. No analysis has been used as a basis."

2. ". . . while city schools may provide their own [courses of study], teachers in small town and rural high schools must either make their own . . . or lean heavily on the adopted textbooks. They usually do the latter."

3. "The materials in the courses of study are too often determined or influenced by the adopted textbooks, which are usually written to meet conditions in large urban centers, rather than small-town and rural communities."

4. "While the producers of courses recognize the variations that need to be made for such communities, they make no provisions for such variations."

5. The treatment of the subject in state courses of study is

too brief to be of great value. "A comparison of the four state courses of study with courses of study for city schools shows that the former devoted approximately only one-ninth as much space to eighth-grade science, and one-fourteenth as much space to science content as the latter."

UNIT IV

Problem.—To determine (1) the occupations of the fathers of children living in the mountainous sections of the region,[1] who were studying eighth-grade science; (2) the vacation activities of these children; and (3) the occupations in which they planned to engage.

Method.—A questionnaire was submitted to eighth-grade pupils of the region, requesting them (1) to state their fathers' occupations; (2) to state the occupations in which they themselves engaged during vacations; and also, (3) to list, "in order of the greatest likelihood" the six occupations in which they would most likely engage. An analysis was made of 514 replies received.

Findings.—1. "Though many occupations are included in the lists, . . . the great majority of persons are engaged in only a few major occupations in the mountain region; and if what people do is any measure of what to teach, then most of the applications can be made in terms of a few principal occupations."

2. ". . . farming, homemaking, and health, industrial, and mechanical problems peculiar to the region are the most essential activities for the territory included in the study."

UNIT V

Problem.—To determine the scientific interests of children living in the mountainous sections of the region, from their questions about scientific topics.

[1] The pupils in this and the following units represented 227 counties in the mountainous sections of the eight Southern Appalachian states.

Method.—A questionnaire which began with an explanation emphasizing useful materials and which provided two model statements, requested the pupils to list the topics they thought most useful to them. From all the schools, a total of 502 pupils responded, listing 5,197 items which represented 186 topics. An analysis was made of the responses received from the pupils of two of the schools to determine the extent to which their statements had been influenced by the textbooks of general science which they had studied.

Findings.—1. "The greatest interest[1] seemed to be in those things dealing with securing a living in the region."

2. "The pupils were considerably interested by what they had already studied in eighth-grade science classes."

3. "Many questions asked dealt with the theoretical side of things rather than the practical."

UNIT VI

Problem.—To determine the reading interests of pupils and parents living in the region.

Method.—The pupils were asked to list the papers and magazines received and read in their homes. The different publications, which numbered 296, were classified in 10 groups. Twelve copies were analyzed from each of these groups having high frequencies of pupil listing, and six "for each of the ones with less frequency." In all, 1,024 copies were analyzed. "Of these 48 were young people's magazines; 48 were educational in nature; 186 were devoted to farm life; 72 were devoted to current events; 108 dealt with the home and interests of women; 21 were news publications local in character; 471 were news publications general in character. The number of square inches of each article was measured regardless of size of type. The measured materials were then classified under the same headings as those used in analyzing the textbooks

[1] For references to other studies of interests, see footnote, p. 235 of this volume.

and classifying the science interests of pupils." (Units II and V.)

Findings.—"If the materials in newspapers and magazines denote the interests of their readers, people are mostly interested in their immediate rather than in their remote surroundings."

UNIT VII

Problem.—To determine the activities in which pupils and their parents engage and to determine which of these activities are appropriate for teaching in a course of general science.

Method.—In a questionnaire the pupils were asked to state the activities in which their fathers, their mothers, and they themselves engaged. This questionnaire was presented orally by the investigator to 72 pupils. A prize was offered to the pupil submitting the best list of "activity situations." A total of 471 activities was submitted. The lists were checked and the activity situations were classified. Another questionnaire, which included the activity situations suggested by this group, was prepared and submitted to the pupils in 12 high schools, who were asked to check those activities in which they, their mothers, and their fathers engaged. The "activity-situations list" was personally presented to 50 teachers of science with the request that they check those items which they thought should not be included in an eighth-grade course of study. The lists were returned by 18 of these teachers. A comparison in "per cent of consideration given" each topic was then made of the results of these studies of activity situations and the results of the analysis of reading interests.

Findings.—". . . persons in the region devote most of their efforts to farming, homemaking, securing and caring for foods, and preservation of health. Other activities are complementary to these."

Table LXXXI presents more detailed results of the analyses.

TABLE LXXXI

A COMPARISON OF THE AVERAGE EMPHASIS ON VARIOUS SUBJECT-MATTER UNITS, AS INDICATED BY THE CONTENT OF EIGHT TEXTBOOKS OF GENERAL SCIENCE, WITH THE AVERAGE EMPHASIS AS REVEALED BY THE READING INTERESTS, SCIENCE INTERESTS, AND ACTIVITY SITUATIONS OF PUPILS IN SCHOOLS OF THE SOUTHERN APPALACHIAN REGION

Units	"Percentages of consideration" given each topic	
	Textbook analysis	Average for the other three analyses
Farming	5.3	24.8
Home in general	4.5	16.9
Health	10.6	13.3
Food and diet	7.2	9.8
Mechanics	13.4	6.3
Animals	1.7	3.7
Recreation	5.3	3.7
Fire protection	1.6	3.6
Life in general	3.3	3.6
Plants	3.5	3.1
Water supply	4.5	2.2
Electricity	5.4	2.0
Weather knowledge	6.4	2.0
Heating the home	7.5	1.7
Lighting homes and buildings	5.5	1.7
Heavenly bodies	8.4	1.5
Ventilating buildings	4.2	1.7

STUDY NO. 171

An Investigation of Content and Mastery of High-school General-science Courses[1]

By Elwood D. Heiss*

UNIT I

Problem.—"To discover the basic instructional material now used in general-science courses; that is, to ascertain the basic facts, principles, and applications of science around which the courses are built."

Method.—An analysis was made of the content of seven textbooks of general science published between 1923 and 1927. "Each page . . . was carefully read and brief statements recorded of the facts, principles, and applications of science developed in them. In some cases a single statement was used to cover more than a single fact or principle. For example . . . 'The operation of a siphon' was given to cover all the facts and principles necessary for its explanation, as there is only one correct explanation of the operation of a siphon. This was done only where there was no doubt as to what instructional material was involved. Quite frequently statements had to be reduced to their lowest terms; for example, . . . 'The physical properties of air' . . . was listed . . . as . . . 'Air occupies space,' 'Air has weight and exerts pressure,' 'Air can be compressed,' and 'Air is elastic.' "

[1] See also analyses of textbooks of general science by Webb and Weckel, *Investigations in the Teaching of Science*, Vol. I, pp. 170–180 and 198–204, respectively; by Klopp and Downing, Vol. II, pp. 70–72 and 72–74, respectively; and by Howe and Davis, in this volume, pp. 63–68.

* Dissertation for the degree of Doctor of Philosophy, Teachers College Columbia University, 1932. Copies may be secured from the investigator at State Teachers College, East Stroudsburg, Pennsylvania. A partial report of this study appears under the title, "Ability Standards in General Science," in *Science Education*, XVI (December, 1932), 479–484.

"After the analysis . . . was completed, the facts, principles, and applications of science were grouped under [12] unit headings to show the frequency of their occurrence in the several texts." The twelve units were *Atmosphere and Weather; Water, Water Supplies, and Sewage Disposal; The Earth and Other Heavenly Bodies; Rocks and Soil; Foods and Nutrition; Life on the Earth; Energy, Work, and Machines; Heating and Lighting; Electricity and Communication; Travel and Transportation; Clothing;* and *Homes and Building Construction.* "No material was considered basic or included in this grouping unless it occurred in at least a majority of the texts."

TABLE LXXXII

BASIC FACTS, PRINCIPLES, AND APPLICATIONS OF SCIENCE AND THE NUMBER OF TEXTBOOKS OF GENERAL SCIENCE IN WHICH EACH APPEARED

FACTS, PRINCIPLES AND APPLICATIONS	NUMBER OF TEXTBOOKS
Unit—*Atmosphere and Weather*	
A. Physical Properties and Mechanics of Gases	
1. Air occupies space	7
2. Air has weight and exerts pressure	7
3. Air can be compressed	7
* * * * *	
B. Chemical Composition	
1. Air is a mixture of gases	7
2. The chief gases in the air	7
* * * * *	
Unit—*Water, Water Supplies and Sewage Disposal*	
A. Physical Properties	
1. Boiling points of water: Centigrade and Fahrenheit	6
2. Freezing points of water: Centigrade and Fahrenheit	6

Findings.—While there is a considerable degree of uniformity, "there is no complete agreement among authors and teachers of general science as to how the instructional material of general science should be organized and developed, except that

the units of subject matter should be organized from the point of view of our environment without any regard to the major divisions of science."

A sample of the "basic facts, principles, and applications of science" is presented in Table LXXXII

UNIT II

Problem.—"To determine the extent of mastery of the basic instructional material of general science," resulting from a year's instruction.

Method.—Objective tests consisting chiefly of multiple-response items, each having five responses, were constructed for the units of subject matter obtained from the analysis of textbooks. The scores on these tests of 366 pupils, who were just completing a year's study of ninth-grade general science in eight selected high schools of Wisconsin having "well-trained and experienced teachers," were secured. The number of correct responses for each test item of each test was determined and from these data the "percentage of mastery," i.e., the percentage of pupils who answered each item correctly, was computed. A comparison was made to determine whether a relationship existed between the percentage of mastery of items of subject matter and the number of textbooks in which these same items appear.

Findings.—1. ". . . most of the facts, principles, and applications of science which are to lead the pupils to a better understanding and control of their environment are not mastered by ninth-grade pupils. It is apparent also that there is considerable variation in mastery of the units of subject matter of general science and also considerable variation in mastery of the various topics within the units themselves."

2. No significant differences were found between the "percentage of mastery of items of subject matter and the number of textbooks in which they appear."

UNIT III

Problems.—(1) To study "the relation of intelligence to achievement in general science"; and (2) to set standards for achievement in general science in terms of the scores on an intelligence test."

Method.—During the school years of 1928–29, and 1929–30, 10 schools, "fairly well distributed geographically," co-operated in carrying on a testing program. In all but one of these schools, either Form A or Form B of the Terman Group Test of Mental Ability was administered to the pupils early in the fall. In this one school, the test was administered in 1927 and the scores were corrected to 1928 by means of a regression equation, and a table for estimating yearly gain on the Terman Test for high school pupils.[1] "Pupil achievement in general science in these schools was determined, by means of the Powers General Science Tests, on December 1, March 1, and June 1. . . . Medians, quartiles, and semi-interquartile ranges were calculated for both tests at each period of testing," as were also the coefficients of correlation (Pearson) between the Terman Group Test of Mental Ability and the Powers General Science Test. The average of these three correlations was .48.

"Ability standards" were then computed in accordance with the method of Symonds.[2] "These ability standards afforded a means by which teachers might determine whether or not the pupils in their general-science classes are working up to their ability levels."

Conclusion.—From the results of this unit it seems evident that "intelligence is a factor which conditions the achievement of pupils in general science."

[1] P. M. Symonds, *Ability Standards for Standardized Achievement Tests in the High School* (New York City: Bureau of Publications, Teachers College, Columbia University, New York City, 1927), p. 47.

[2] Symonds, *op. cit.*, Chapter II.

STUDY NO. 172

Cultural Natural Science for the Junior High School

By Paul Ammon Maxwell*

UNIT I

Problem.—To formulate objectives and procedures for a program of cultural natural science for the junior high school.

Method.—The major objectives of public education enumerated in 18 sources were analyzed and listed under five categories: *Health Habits*, *Social Duties*, *Vocational Duties*, *Diversions*, and *Self-regimentation Activities*. The importance of *Diversions* as a major objective was evidenced by the fact that 20 statements of objectives belonging in this category were found in the 18 sources analyzed. A questionnaire was sent to 565 teachers of general science from whom were received 190 replies. In 178 of these the value of cultural natural science was indicated by the expression of the belief that "diversions or avocations are important objectives of general science." The "specific objectives of cultural-natural-science education" were then defined by the investigator as "growths in desire and ability to achieve pleasant and wholesome diversions through the appreciation of natural-science themes."[1]

An examination was made of 12,528 titles of both magazine articles and chapters in books intended for both juvenile and adult lay readers. From these titles were selected 2,800 suggestive of themes suitable for cultural science. A set of

* Baltimore: The Williams and Wilkins Company, 1932. A report of this study appears under the title, "A List of Objectives for Cultural Natural Science," in *School Science and Mathematics*, XXXIV (November, 1934), 875–880.

[1] A theme was defined as some aspect of "natural wonders and achievements, or related groups of natural wonders and achievements," selected in order to stimulate activities promoting the diversion of the individual.

criteria was formulated to guide the further selection from these titles of a "Preliminary List of Themes" possessing, for junior-high-school pupils, high value with respect to "cultural" rather than "practical natural-science education" (such as might be assumed for themes of civic, health, and vocational types). The criterion for the list as a whole was—

Range, as evidenced by the inclusion in the list of a variety of such themes as "Natural Wonders of the Heavens," "The Earth," and the like; "Discoveries and Inventions in Astronomy," "Geology," etc.; "Human Enterprises in the Fields of Agriculture," "Food and Clothing Industries," and the like.

The criteria for the individual themes were—

Quality, as evidenced by its possession by the component themes "to a notable degree" of such qualities as beauty, mysteriousness, dangerousness, uniqueness, comicality, unexpectedness, rarity, and importance

Scope, as evidenced by its capability of providing "worthwhile appreciations if pursued only for a few hours," and also of "expanding into a lifelong source of diversion"

Wording, as evidenced by its statement "in the form of a title and subtitle appropriate for an exposition of the theme; in terms that emphasize its cultural values; in terms that make clear its scope;" and "in terms that will be easily and uniformly interpreted by the judges"

These themes were next sorted into groups of such a nature as to insure that the list possessed the desired *Range*. "The titles in each of these groups were re-sorted into smaller homogeneous groups and organized around topics which were formulated to serve tentatively as themes for the Preliminary List." The resulting list consisted of 421 themes of which the following is a sample:

Sub-Group A. Natural Wonders of the Heavens.

Theme 1. The moon—curious facts about our nearest celestial neighbor
The moon's mysteries
Formation of moon and earth
Gravity on earth and moon
Volcanoes or cosmic shell-holes (moon craters)
Satellites
The moon falls

This list of themes was next submitted to 16 judges, of whom 12 were people outstanding in the field of natural-science education, and four were editors experienced in selecting science materials for lay readers. These judges were believed by the investigator to possess "(a) a broad knowledge of natural-science subject matter, (b) a familiarity with the tastes and abilities of junior-high-school pupils, and (c) an understanding of the characteristics of cultural natural science as distinguished from *practical* natural science." Each evaluator was asked to place *A*, *B*, or *C* before each theme to signify his judgment of whether it was "Very Valuable," "Of Moderate Value," and "Of Little or No Value." A comparison of the evaluations by the two groups, the educators and the editors, revealed no significant differences; hence the judgments of both groups were combined. Relative values of the themes were determined on the basis of assigning values of respectively 100, 50, and 0 points for evaluations of *A*, *B*, and *C*. The themes which had values on this composite rating of from 72 to 100 points were made the "Final List." The reliability of the evaluations was determined by an elaborate series of computations of coefficients of reliability; the index of reliability for the 16 judges was determined by the Spearman Prophesy Formula and was found to be .80 $\pm$ .012.

Findings.—There were on the Final List, 108 themes, of which the following are samples:

Sub-Group A. The Heavens

1. The moon—curious facts about our nearest celestial neighbor
2. Our flaming friend—what we know about the sun
3. Star wonders—marvelous revelations of modern astronomy

* * * * *

Sub-Group B. The Earth

13. When the earth was young—formation of the ball on which we live
14. The earth changes its face—about the forces that slowly reshape the earth's surface
15. When the earth quakes—what science has revealed about our trembling globe

UNIT II

Problem.—To prepare a learning manual by means of which to evaluate each of four themes with respect to its merits for developing cultural natural science.

Method.—Four manuals were constructed "in harmony with the following hypothetical principles of cultural-natural-science education":

> Cultural natural science should be an elective field of education.
>
> The particular themes to be studied and the particular learning activities to be carried out in studying them should be elective.
>
> Guidance in the form of suggestions rather than requirements should be offered by the teacher in such cultural activities as reading, giving talks, writing articles, debating, staging plays, making observations, experimenting, and making booklets, models, collections, and exhibits.
>
> The learning activities should be considered by teachers and pupils as diversions rather than as duties for the latter to perform.
>
> Progress in the study of a theme should not be stimulated or rewarded by marks or credits.

". . . the acquisition of exact information and technical skill, which are so important in vocational, civic, physics, and other practical kinds of education, were not considered important objectives of the exercises," since it was feared by the investigator that emphasis upon these objectives might "defeat the primary purpose of cultural education."

"Each of the four learning-exercise manuals prepared in accordance with these principles consisted of . . . first, an exposition of the theme, designed to offer some appreciations and to arouse interest; and, . . . a 'follow-up' in which various activities were suggested by means of which the learner might secure the desired growths." "The expositions were written in simple, non-technical language; and such artistic devices as figures of speech, paintings, photographs, diagrams, and allusions to human experiences were used freely." The "follow-up" activities in each manual provided an "exhaustive reference list, suggesting books, pamphlets, and magazine

articles possessing qualities similar to those outlined for the exposition." Each manual proposed, also, "direct observations of objects or processes by means of trips and experiments." Finally, such creative or cultural activities as those included in the principles of construction of the unit were suggested.

These four manuals were first tried out in a typewritten form with 63 eighth-grade and ninth-grade pupils. Each pupil selected the manual and engaged in such of the follow-up activities suggested in it as appealed to him. The pupils worked individually or in small or large groups. The manuals were evaluated on the bases of (1) "the extent to which they provided the pupils with enjoyable experiences, (2) the extent to which they increased the interests of the pupils in the respective themes, and (3) the extent to which the pupils preferred the study of the manuals to the study of a general-science textbook." Data for these evaluations were collected on blanks filled out by the pupils.

The manuals with minor revisions suggested by the preliminary try-out, were tried out in 60 junior high schools with 383 eighth-grade and ninth-grade pupils (211 boys and 172 girls), representative of low, medium, and high scholarship. Elaborate directions were given to both the teachers and the pupils. At the beginning of the experiment each pupil was asked to indicate on a Preliminary Attitude Blank whether he liked, disliked, or neither liked nor disliked each of 83 terms commonly found in general-science textbooks, and 40 others selected from the four learning manuals. At the close of the six weeks' tryout each pupil was asked to fill out a Pupil Data Blank containing questions "concerning growth of interest in the manual themes," and "the kind of science course preferred." The blank contained, also, a request for criticisms of the manuals, and a reproduction of the Preliminary Attitude Blank accompanied by the request for the pupil to evaluate the items again without premitting his previous responses to these same items to influence him. The Teachers' Data

Blanks, filled out at the close of the tryout, "contained a request for information concerning the sex, I.Q., general scholarship, and science standing of each pupil participating in the study"; and also a request for criticisms of the manuals, and for the teacher to check the terms in the list of scientific terms which the pupils had studied "as part of their regular classwork *after* filling out the Preliminary Attitude Blanks and *before* filling out the Pupil Data Blanks.

Findings.—The manuals were found "to be effective in increasing pupil interests in science themes; to be preferred by pupils to the conventional type of general-science course; to be more effective than the conventional type of general-science course in increasing likes and decreasing dislikes for science subjects and activities; to emphasize learning devices that are preferred by pupils to the learning devices emphasized in the conventional type of general-science course; to have no serious weaknesses, in the opinions of the participating teachers and pupils; and to be considered by the teachers [to be] superior for cultural purposes to the conventional type of science course."

STUDY NO. 173

Can and Should General Science Be Standardized?

By C. M. Howe*

Problem.—To determine the aims[1] and the fundamental topics,[2] or minimum essentials, of general science.

* *School Science and Mathematics*, XIX (March, 1919), 248–255. A request was made by a member of the N.A.R.S.T. that this study be included for its historic interest and value. It received a sufficiently large favorable evaluation on the second questionnaire to entitle it to inclusion.

[1] See also analyses of aims of general science by Weckel, Crecelius, and Watkins, *Investigations in the Teaching of Science*, Vol. I, pp. 198–199, 231–233, and 252–254, respectively; and by Pruitt and Cureton, Vol. II, pp. 65–67 and 87–90, respectively.

[2] See also studies of content of general science by Washburne, Webb,

Method.—A questionnaire was prepared which included a list of nine aims which the investigator "had found most commonly championed in the articles on general science, prefaces to texts, and discussions of science values in education." Following this list of aims was a long list of topics suitable to the course in general science, "compiled from a study of texts, syllabi, and courses, and from analyses of texts . . ."

A list of names of teachers of general science was secured from the editor of *General Science Quarterly*, and from this list, 150 were selected "on the basis of wide geographical distribution and similarity of conditions and problems with those of Cincinnati" (where the investigator taught).

The questionnaire was sent to each of these teachers who were asked to rank the aims in the order which, in their judgments, indicated the relative importance of the aims; and to mark the topics as "Fundamental" (*F*) or "Supplementary" (*S*), in accordance with their opinions with respect to whether the topics were "essential to any course in the subject, or only of possible value as optional material." Eighty usable replies were received.

Findings.—1. "A close analysis of the first list will show a remarkable consistency of this judgment of the majority of our 80 teachers with the three basic aims: environment, application, information."

The aims of general science in descending order of relative importance as indicated by the opinions of the respondents follow:

Weckel, Pollock, Meier, and Curtis, *Investigations in the Teaching of Science*, Vol. I, pp. 153–155, 170–180, 198–204, 265–267, 305–309, and 326–333, respectively; by Downing, Heiss, Richie, and Powers, Cureton, Curtis, and Harap and Persing, Vol. II, pp. 72–79, 80–83, 87–92, 92–96, and 97–100, respectively; and by Wolford, Heiss, and Davis, in this volume, pp. 47–53, 54–57, and 66–68, respectively.

The aim of general science is to give each child

Understanding, appreciation, and control of his everyday *environment*
Appreciation of the *applications* of science in industrial and social life
A fund of valuable *information* about nature and science
Training in use of the *scientific method* in solving problems
Preparation and foundation for later study of special sciences
Interest and motivation in school work to prevent his elimination
A *vocational* survey of sciences to guide and inspire life work
Appreciation of the unity and beauty of science and of its master minds
Training in cold, scientific thinking involving self elimination

2. No topic was considered to be of fundamental importance in the course in general science, by more than 95 per cent of the respondents.

The fundamental topics, or minimum essentials, and the optional topics of general science, in descending order of relative importance as indicated by the opinions of the respondents follow:

FUNDAMENTAL TOPICS, OR MINIMUM ESSENTIALS, OF GENERAL SCIENCE

Water—physical properties and mechanics of liquids
Air—chemical composition and combustion
Air—physical properties and mechanics of gases
Ventilation
Household heat and light
Water supply and purification
Weather and climate
Bacteria, yeasts, and molds
Foods, diet, and digestion
Combustion and fuels
Hygiene and sanitation
Water—chemical properties
Plant life—elementary botany
Everyday chemistry (salt, ammonia, carbon, etc.)
Simple machines
Force, power, and energy
Animal life—elementary zoology
Systems of measurement
Acids, bases, and salts
Elements, compounds, and mixtures

Density, specific gravity, and buoyancy
Electricity and magnetism

SUPPLEMENTARY TOPICS—OPTIONAL MATERIAL OF GENERAL SCIENCE

Household chemistry (soda, stains, etc.)
Coal, gas, and petroleum
Molecular theory
Light and its relation to life
Astronomy and star study
Soils and rocks
Steam and gas engines
Plumbing and household appliances
Sound and its relation to life
Cooking and baking
Elements of physiology
Iron, steel, and metals
Trees and flowers
Theory and laws of heat
Drugs, narcotics, and alcohol.

STUDY NO. 174

ANALYSIS OF THE SUBJECT MATTER IN THE EIGHT MOST WIDELY-USED TEXTBOOKS IN GENERAL SCIENCE[1]

BY IRA C. DAVIS*

Problem.—To determine what subject-matter topics are discussed in the eight textbooks of general science most widely-used in Wisconsin.

Method.—An analysis was made of the content of the latest editions available in the school year of 1929–30 of the eight textbooks of general science most widely used in Wisconsin at that time. The units under which the subject-matter topics

[1] See also analyses of textbooks of general science by Webb and Weckel, *Investigations in the Teaching of Science*, Vol. I, pp. 170–180 and 198–204, respectively; by Klopp and Downing, Vol. II, pp. 70–72 and 72–74, respectively; and by Heiss, in this volume, pp. 54–57.

* *School Science and Mathematics*, XXXI (June, 1931), 707–714.

were to be organized were those revealed by the results of this analysis and of earlier similar analyses.

The different textbooks were first studied in order to determine what topics were to serve as the nucleus for the final list. The textbook which was found to contain the greatest number of topics for a given unit provided the basic text for that unit, to which appropriate topics from the other texts were added as the final analysis revealed them. A topic was retained, and was credited to every textbook in which its discussion provided sufficient material to make the topic teachable without supplementation from another source. The necessary information concerning the topic might be furnished by the text material, by a diagram, or by an experiment. Thus, the complete analysis revealed all the topics discussed in the eight textbooks together with the number of books in which each topic was adequately discussed.

In the final tabulation only those topics (with five exceptions) were retained which were "acceptably presented" in at least 75 per cent, i.e., in six or more of the eight textbooks.

Findings and Conclusions.—1. Of the total of 137 topics, 73 occur in all eight textbooks; 37, in seven; and 22, in six. The five topics which were retained though they appeared in only five textbooks, were so retained because "there was some doubt whether the topics were treated completely enough" to be considered "acceptably presented" in others of the texts.

2. "There is a high agreement in the textbooks for the units, *Air, Water, Heat, Weather and Climate, Light, Magnetism and Electricity, Energy and Machines, Plants, The Human Body,* and *Foods.* There is a fair agreement in the units, *Sound, The Solar System,* and *Rocks and Soils.* . . . There is very little agreement in the units on *Animals and Clothing.* It is questionable whether there is enough acceptable material to retain the units of *Sound, Animals,* and *Clothing,*" since in some of the textbooks the materials of these units are discussed as parts of other units.

3. "The results of the investigation demonstrate clearly that our leading textbooks in general science do agree on subject matter. They are no longer a hodge-podge or piecemeal mixture of science. While the agreement in subject matter in general science is not so high as it is in physics, it is higher than it is in biology or chemistry. Of the 137 accepted topics, the least number accepted for any of the textbooks is 113 and the highest is 134. Over 53 per cent of the topics are found in all of these books, 27 per cent in seven, and 16 per cent in six. Over 96 per cent of the material is found in at least six of the eight books.

A sample of the subject-matter topics is presented in Table LXXXIII.

TABLE LXXXIII

THE UNITS, THE TOPICS IN EACH UNIT, AND THE NUMBER OF TEXTBOOKS IN WHICH EACH TOPIC OCCURS

TOPIC	NUMBER OF TEXTBOOKS IN WHICH TOPIC OCCURS
Unit—*Air*	
Air occupies space	7
Air has weight	8
Air exerts a pressure	8
* * * * *	
Unit—*Water*	
Composition of water	6
Water and solution	8

STUDY NO. 175

RESULTS OF A THREE-YEAR SCIENCE SEQUENCE IN JUNIOR-HIGH-SCHOOL GRADES

BY HARRY A. CARPENTER*

UNIT I

Problem.—To determine whether pupils who had received five or six semesters of instruction in general science in Grades VII, VIII, and IX made higher examination scores subse-

* *Science Education*, XVII (October, 1933), 183–192.

quently in physics and chemistry than other pupils who had studied general science fewer than five semesters; and (2) whether on the whole pupils who had studied general science made higher examination scores in physics and chemistry, subsequently, than those pupils who had substituted a year's study of elementary biology for work in general science.

Method.—The results in the final examinations of 411 pupils in physics and of 664 pupils in chemistry were recorded for the pupils who completed these courses in the high schools of Rochester, New York, in June, 1928, and in January and June, 1929. Comparisons were made between the median scores of all the pupils in each course, physics and chemistry, who had studied general science for five or six terms (two, three, and five 50-minute periods per week in respectively the seventh, eighth, and ninth grades); and the median scores of all who had studied general science for less than five terms; and also between the median scores of all the pupils in each course who had studied general science, and the median scores of all who had studied elementary biology.

Findings.—1. The pupils who had studied general science for five or six terms made consistently higher median scores in the final examinations in physics and chemistry than did those who had studied general science for less than five terms.

2. The pupils who had studied general science made consistently higher median scores in the final examinations in physics and chemistry than did those who had studied elementary biology.

UNIT II

Problem.—To determine whether or not there is a consistent increase in knowledge of general science resulting from an increasing number of semesters devoted to the study of the subject.

Method.—A comparison was made of the medians of the examination marks, in June, 1929, of three groups of IX-B

pupils, those who had studied general science for respectively five, four, and three terms. Also in June, 1931, a comprehensive test was given to all pupils who were studying general science in grades VII-B and -A, VIII-B and -A, and IX-B in the junior high schools; and to all those who were studying general science in grade IX-B in the senior high schools of Rochester. An extensive test consisting of multiple-response and best-answer items and of items involving the use of diagrams, charts, etc., was prepared by a committee of teachers, who first determined upon the objectives to be tested and then devised items to test those objectives. "In January, 1932, the same test was given again to all IX-B pupils in the city that were taking general science."

Findings.—1. Of the ninth-grade pupils who had just completed their study of general science, those who had studied the subject for five terms made a median score about 5 per cent higher than those who had studied the subject for four semesters and more than 10 per cent higher than those who had studied the subject three terms.

2. The results of the 1931 test showed "a definite increase in arithmetic mean from VII-B to IX-B, an increase in the lowest score and consistent increases in the highest scores."

3. The mean score from the IX-B pupils who had had four previous terms of work in general science was about 11 per cent greater than that of the IX-B pupils who had entered high school without this previous training in general science.

4. "The arithmetic mean . . . of the January class [of 1932] shows a satisfactory improvement over the record . . . made by the same pupils six months previous."

UNIT III

Problem.—"To determine whether guessing may not have contributed to the results so largely as to invalidate the test."

Method.—The test previously administered was copied in code, with numbers and letters substituted for the printed

materials of the test. This blank test was then submitted to 75 pupils, including those who were then studying science in the ninth, eleventh, and twelfth years, and to1 5 Seniors of the University of Rochester. The directions were to guess the correct answer to each item and to indicate it by checking the desired letter.

Findings.—"In every grade the highest score [made on the regular test by similar groups] was much in excess of the highest score obtained in guessing."

Conclusion.—"While the data presented do not warrant final conclusions, they do present strong evidence in favor of three continuous years of science training in the junior-high-school grades, as compared with one year of either general science or elementary biology, or with less than five semesters of general science."[1]

STUDY NO. 176

The Relationship between the Ability to Recall and the Ability to Infer in Specific Learning Situations

By Ralph C. Bedell*

Problem.—To determine the relationship between the ability to recall and the ability to infer in specific learning situations, when science materials are used for the situations.

[1] See also investigations of the values derived from the study of general science by Leker, Dvorak, Cramer, Carpenter, and Black, *Investigations in the Teaching of Science*, Vol. II, pp. 60–70, 122–125, 125–129, 129–133, and 239–246, respectively; and by Hurd, in this volume, p. 123.

* Dissertation for the degree of Doctor of Philosophy, University of Missouri. Published as a Bulletin of the Northeast Missouri State Teachers College, Kirksville, Missouri, Vol. XXIV, No. 9, (December, 1934). Copies can be obtained from the author at Warrensburg, Missouri. A report of this study appears under the same title in *Science Education* XVIII (October, 1934), 158–162.

Method.—Each of 30 of the 93 principles of science found by Downing[1] in 20 textbooks of science was made the basis of a paragraph, planned to "give certain facts from which the desired science principle or generalization could be inferred." "For each paragraph two sets of test items were constructed, one set designed to measure recall and the other to measure inference." Each test was of the multiple-response type and each item "included one choice which is scientifically true but which was not given in, nor could reasonably be inferred from, the paragraph, and one choice which was more or less platitudinous." "The recall test for each paragraph consisted of five such multiple-choice items. . . . In every case the correct choice on a recall item is an exact reproduction of a certain statement given in the paragraph." "The inference test for each paragraph consists of five statements, one of which is the correct inference . . . These five statements are represented to the subject as being possible conclusions to the paragraph, from which he is to select the best one and place a cross in front of it."

The recall and inference tests were combined so that the inference items were placed first on one half of the tests and the recall items first on the other half. The reliability of these tests, subsequently determined by computing the coefficients of correlation of the scores on the halves, "was found to be sufficiently high."

The tests were administered to an experimental group composed of 184 boys and 140 girls, who were pupils of the eighth-grade and ninth-grade classes of general science in Jefferson Junior High School, of Columbia, Missouri, and in Southwest High School, of Kansas City, Missouri. The mean chronological age of the pupils was 14 years and two months with a range from 12 years to 17 years and five months. Of the entire

[1] E. R. Downing, "An Analysis of Textbooks in General Science," *General Science Quarterly*, XII (May, 1928), 509–516. See *Investigations in the Teaching of Science*, Vol. II, pp. 72–79.

group, 284 had already studied general science for approximately two semesters, and 60, for approximately one semester. The average I.Q., as determined from scores on the Terman Group Test of Mental Ability, Form A, was 107.9 with an S.D. of 14.3.

The Bedell test was administered to all members of the group. The two forms were distributed alternately in such a way that approximately one-half the pupils received each form. The test was administered on either three or four consecutive days; the total testing time was held constant at 120 minutes. "The test was given in such a way that the subject could not see both a paragraph and the questions on it at the same time nor could he turn back to a given paragraph after having started the questions on it. Uniform directions were used by the author, who administered all the research tests."

The results of the tests were given an elaborate statistical treatment which included the computations of means, S.D.'s., Medians, Q_1's, Q_3's, coefficients of variability, and ranges of the scores of all the pupils on all the tests. Similar comparisons were made for the scores of the pupils who were divided into three groups composed respectively of the 25 per cent having the lowest intelligence, the 25 per cent having the highest intelligence, and the remaining middle 50 per cent. Inter-test correlations and self correlations were also computed, from the scores on the Bedell test, of the entire group and of 75 per cent of the most intelligent members. Inter-test partial correlations and self-test partial correlations were likewise computed for the scores of the entire group on the Bedell test and for the scores of the groups of pupils representing the three intelligence levels.

Conclusions.[1]—1. "The bulk of the evidence . . . indicates that the ability to recall and the ability to infer . . . are different abilities."

[1] Only those conclusions from an extensive list are here included which pertain more or less directly to the teaching of science.

2. "The boys perform better on the Inference Section of the Bedell Test than the girls. Such sex differences are not found for the Factual Recall Section of the Bedell Test nor for the Terman Group Test of Mental Ability, Form A."

3. "The subjects who had received only one semester of general-science training show no significant differences in performance . . . from the subjects who had received two semesters of such training."

4. "It is practically impossible for the general-science students who rank in the lower 25 per cent in intelligence to infer generalized science principles from rather typical general-science situations. The performance of this group on the Inference Section of the Bedell Test is about equal to that which would be expected from the operation of chance alone."[1]

5. "The only group of students studied in this investigation who could infer a fair number of generalized science principles from rather typical general-science situations was the upper 25 per cent in intelligence."

6. "It appears that there is a level of intellectual development below which students with the present type of training cannot be expected to infer even a fair number of generalized science principles from typical general-science situations. This level is probably as high as, or higher than that represented by the average score for the ninth grade on the Terman Group Test of Mental Ability, Form A."

7. "It also appears that teachers consider the ability to infer a significant ability which enters into the ability to get marks" —more significant, in fact, than the ability to recall. "This indicates the rather high probability that teachers are attempting to mark a large number of students on an ability which the students cannot use successfully." ". . . it would seem desirable to give additional training in the ability to infer . . ."

[1] Compare these conclusions with those of Haupt and Croxton, pp. 19–27 and 33–36, respectively of this volume

8. "The wide range of scores on the various tests employed . . . emphasized the extent of individual differences among students even in a fairly well selected group."

STUDY NO. 177

A Comparison of the Relative Effectiveness of Two Methods of Teaching General Science

By J. Darrell Barnard* and Martin L. Robertson

Problem.—"To compare the relative effectiveness of a 'teacher-prepared study-guide' method and a 'pupil-developed study-guide' method of teaching general science, with respect to both immediate and delayed reaction to 'paper-and-pencil' tests."

Method.—Two classes in general science in the Ault Consolidated School and two others in the Laboratory School of Colorado State College of Education, 140 pupils in all, were equated on two bases: scores on the Van Wagenen Reading Scales in General Science and on pretests over the nine units of science used in this study. "Due to the presence of pupils who presented uncontrolled irregularities, the groups were equated separately for each of the nine units and again at the close of the study." The groups were considered to be equivalent when the difference of their mean scores divided by the standard deviation of the difference of their mean scores was less than 1.00.[1]

Two major units, dealing respectively with geology and biology, were constructed around major and subsidiary principles. The materials necessary to the study of these units were selected from several sources and prepared in two mimeographed booklets. "Two techniques were used to guide the

* *Science Education*, XX (December, 1936), 200–206.

[1] Henry E. Garrett, *Statistics in Psychology and Education* (New York: Longmans, Green and Company, 1926), p. 133.

pupils in obtaining an understanding of these unit problems, a 'teacher-prepared study-guide' and a 'pupil-developed study-guide' method." "Prior to the experiment it was necessary to give each pupil practice in the techniques of the two methods. Ten weeks were spent in all four classes on the two units, practicing the development of study guides." The study guides were first prepared by one of the investigators who divided the unit problems into several subsidiary problems upon the basis of these criteria:

Each problem when solved must contribute to the solution of the unit problem
Each problem must develop one idea
The problems should be arranged in a definite order
The problem should be stated clearly and concisely

'Under each of the subsidiary problems were listed questions to answer and activities to perform which, if understood, would solve the problem. At the end of each subsidiary problem, provision was made for summarizing into one large concept those ideas built up by answering the questions and performing the activities. At the end of each guide sheet further provision was made for summarizing the subsidiary concepts into one major concept."

"The pupils were first taught to recognize problems through the medium of carefully planned lessons involving situations from which they were to derive problems in the form of questions. The problem must be so worded that the answer would clarify the situation. Later two consecutive study guides were developed under the direction of the teachers. The entire class was encouraged, by directed questions to recognize and state the questions and activities necessary to the solution of the . . . unit problems . . . Each pupil evaluated his problems and activities on the basis of criteria similar to the four used by the teachers."

"To insure identity of training, the preliminary experiment was begun at Ault a week in advance and a competent stenog-

rapher secured a word-for-word record of each class period. This material was transcribed daily and was subsequently used as an outline in the laboratory-school classes."

After a study guide was made for a unit, the class solved the problems by reading books, magazine articles, and other printed information, by observing phenomena, by interviewing somebody, by asking questions, by observing graphs, charts, tables, diagrams, and pictures, and by experimenting.

"With each method the teacher introduced the unit with an oral preview. The group working with the 'pupil-developed study-guide' method would then proceed to make their own study guide, by group discussion in which the teacher participated. Care was taken to insure that all the fundamental elements of the 'teacher-prepared study guide' were included. These pupils then proceeded to answer the questions and perform the activities involved. The group working with the 'teacher-prepared study-guide' method was given a prepared, mimeographed guide sheet upon which they immediately began working. In both groups each pupil wrote out and handed in a solution of the problem for each unit."

"The tests used in this investigation were objective and were composed of about fifty items per unit. Three types of items were used: The first part of each test involved the ability of the pupil to pick out true statements which applied to the generalizations developed in the unit. The second part of each test involved the elements of problem solving. The third part of the test consisted of situations involving scientific attitudes . . . Each unit test was administered to the groups before the period of instruction. It was repeated at the close of the period of instruction to test for immediate outcomes and again, eight weeks later, for the purpose of measuring retention."

"The experiment was continued for nine weeks, one pair of groups devoting five 45-minute periods a week and the other pair five 50-minute periods a week to the study of science."

"The following factors were kept identical for each pair of

groups: (1) the text materials, (2) the teacher, (3) the length of period, (4) the date upon which a particular unit was presented, (5) the preview, (6) the tests, and (7) the room and equipment for experimenting. All the materials used by the experimental groups were kept in the classroom. All guide sheets, papers, and reference materials were passed out and collected daily. Care was also taken to insure that all the items covered in the tests were included in the units."

The rotation method of experimentation with equivalent groups was used, in accordance with which each group studied successive units by each method in turn. The relative effectiveness of the two methods was determined by dividing the difference in mean gains by the standard deviation of the difference in these mean gains for each unit.

Findings.—In 14 of the 18 separate investigations the advantages were in favor of the "pupil-developed study-guide" method, and four of these advantages were statistically significant for immediate retention; and in 12 of the 18 cases the advantages were in favor of this same method for delayed recall though none of these advantages was statistically significant.

Conclusions.—1. "This 'pupil-developed study-guide' method has some advantages over this 'teacher-prepared study-guide' method with respect to gains upon both immediate and delayed tests composed of items involving scientific attitudes, problem solving, and application of generalizations though the results in general are not statistically significant."

2. "When economy of time is considered those pupils working with this 'pupil-developed study-guide' method spent less actual time in solving the problems on their study guides and secured better results than did those pupils working with this 'teacher-prepared study-guide' method."

Implications.—"This study may be interpreted to suggest that a relationship exists between the amount of pupil participation in the organization of study guides and learning

activities and the amount of growth in the abilities measured by these 'paper-and-pencil' tests. It should be remembered also that this 'pupil-developed study-guide' method obtained whatever advantages are inherent in directed oral discussion which this 'teacher-prepared study-guide' method did not afford."

STUDY NO. 178

Published Workbooks *versus* Pupil-made Notebooks in Ninth-grade General Science

By George W. Peterson* and Harl R. Douglass

Problem.—To determine the relative values of the workbook and the notebook.

Method.—This investigation was conducted "during 1932–33 and 1933–34 in the Drum Hill Junior High School at Peekskill, New York. Four pairs of equated sections of pupils in general science were employed in the experiment. With one section of each pair a commercially published workbook was employed. In the other section of each pair the pupils kept notebook records of their laboratory experiments and experiences, together with the key-words necessary to understand the terminology of the subject matter, additional problems, and projects, and various drawings and diagrams incidental to a course of this kind. In the workbook the problem of an experiment was given; the drawings of apparatus were usually supplied, though not labeled; the procedure was described; and blank spaces were left in which the pupil was to fill in his observations, computations, conclusions, and practical applications. The pupils using the 'self-made workbooks' wrote out all these things in the notebooks."

"From each pair of sections only the records of those pupils were studied for whom pupils of equal ability could be found in

* *The School Review*, XLIII (October, 1935), 608–613.

the other section of that pair. The pupils were paired on the basis of I.Q. (on the Otis Group Intelligence Scale, Advanced Examination), chronological age, and score made at the beginning of the year on an objective test covering the work of the year. Boys were paired with boys and girls with girls."

"In 1932–33 each of three teachers taught one section as a workbook section and one section as a notebook section. The following year one of these teachers conducted the experiment with two sections. As far as could be determined, there were no significant differences in time of day, absences of pupils, rooms or equipment, distractions, or other factors which would effect differences in instructional efficiency. The sole difference, the experimental factor, was the difference in the type of workbooks used."

"The progress of the class was measured by the following means: (1) assignment tests over units of the course, (2) an objective test given at the end of the first semester, (3) an objective test given at the end of the third quarter of the school year, and (4) the New York Regents' Examination in General Science."

"To the pair of sections employed in the experiment of the second year, the Ruch-Popenoe General Science Test was given at the beginning and again at the close of the year, and the gains were taken as measures of the growth of the pupils."

The significance of the results was determined on the basis of the average gains of the various sections with workbook and notebook.

Findings.—"Of the 12 differences obtained with the first four tests but two are large enough to give any great assurance that they are not attributable to chance errors. These two differences favor the notebook method. Of six differences large enough to be indicative, five favor the notebook method. Of the two sections for which gains on the Ruch-Popenoe test were available, an indicative but not fully reliable difference favors the workbook section."

Conclusions.—1. "The results of this study are in general agreement with those of the other investigations cited."[1]

2. "As far as the outcomes of instruction that can be measured by written examinations are concerned, there seems to be little demonstrable difference in the relative efficiency of the workbook and of the notebook as a device for teachers in general science in Grade IX, though the results suggest the probable but slight superiority of the notebook technique."

3. "One teacher may secure better results by use of workbooks and another by use of notebooks."

4. "If there is any relation between the intelligence of pupils and the relative efficacy of either method, the notebook is slightly better for pupils with lower intelligence quotients and the workbook for pupils with higher intelligence quotients. Apparently the writing and the drawing involved in making notebooks are more helpful in fixing facts for the pupils with low intelligence quotients than for the brighter pupils."

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[1] Studies by Moore, Dykhouse, and Curtis, and Stubbs, *Investigations in the Teaching of Science*, Vol. II, pp. 119–122 and 317–320, respectively; by Hurd, pp. 143–146, of this volume; and by Stuart C. Powers, A Study of the Self-made Pupil Laboratory Manual *versus* the Traditional Laboratory Manual. Master's Thesis (unpublished), Ohio State University, 1931.

[2] In accordance with the criterion repeatedly stated and indicated by members of the N.A.R.S.T. in connection with their evaluations of the studies presented in this book, no title is included in this bibliography as a report of a research investigation unless it presents a statistical treatment of data obtained in an attempt to solve, by investigational techniques, a clearly stated or indicated problem.

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STUDY NO. 179

High-school Biology Content as Judged by Thirty College Biologists

By Otis W. Caldwell* and Florence Weller

Problem.—To determine the opinions of college biologists concerning the factual and topical content of high-school biology.

Method.—From 21 "biology textbooks offered for use in secondary schools," the 11 which were believed by the investigators "to be the most extensively used, were selected for detailed analysis as to their factual and topical content. An elaborate chart of these topics and their contents was developed so that the contents of each textbook could readily be compared with that of the 10 others. A summary of all the topics on the chart was then prepared. This summary was condensed to four typed, single-spaced pages," by the omission of details.

The summary was sent to 37 eminent college biologists with a letter explanatory of the study. Also this "Explanatory Note" was used as a preface to the summary:

> The subject-matter content of 11 textbooks designed for use in high-school biology courses has been analyzed and classified. The number of these texts which include each topic is given in the first right-hand column. Will you please place a check mark (✓) in the second right-hand column of all topics you think should be included, leave it unmarked if you would omit it, and write a note or phrase in case you wish to qualify your reply. You may write this note or phrase in the spaces below each question indicating by letter the part of the question to which you refer. Also, add pages if you desire to express yourself more fully than possible on these sheets.

The biologists were also invited to suggest additional topics and procedures which they thought desirable in secondary biology.

* *School Science and Mathematics*, XXXII (April, 1932), 411–424.

Thirty of the biologists returned their copies of the summary with their reactions indicated.

Findings.—1. "Between two-thirds and three-fourths of the college biologists reporting would increase subdivisions of biology [as ecology, taxonomy, morphology, genetics, embryology, anatomy, physiology, bacteriology, and the like], and would present brief definitions of each one."

2. "Classification of plants and animals according to nearly all the judges would be given slightly less attention, although relatively small space is now given this topic in most of the text outlines. However, most recommend naming the large divisions and giving a short description of one type form for each large division."

3. Over four-fifths of the judges "think the course should include brief study of elements, compounds, energy, physical and chemical change."

4. " 'Geographic Distribution of Plants and Animals,' a topic which is not now well represented in the course, is recommended by more than four-fifths of the judges."

5. " 'Human Behavior' and 'Mental Hygiene' would receive relatively small consideration by the judges, though most of them would include the topic."

6. "Although more than 90 per cent of the texts treat 'Alcohol, Tobacco, and Drugs,' less than two-thirds of the biologists would include these topics and those would not give extensive treatment of them."

7. "Almost none of the judges would have a biology course either omitting man or making man the leading feature of the course. All but two would compose the course of structures and functions of plants and animals including man."

8. "Almost all would include care of special human structures, public health, and study of foods."

9. "In ecology, the aspects recommended by nearly all the biologists are economic value of plants and animals, insect pest control, and conservation of wild life."

10. "Processes of metabolism would be included by almost all the judges."

11. "Almost all would include heredity and environment, but would not give large space to the topic."

12. "Theories of evolution would be given scant attention."

13. "Biography of a dozen or more biologists would be included, the list consisting of men who have made the most fundamental contributions to biology." (The 13 most important biologists in the combined opinions of these biologists were Mendel, Pasteur, Charles Darwin, Leeuwenhoek, Linnaeus, Koch, Lamarck, Schwann, Lister, Huxley, Schleiden, Harvey, and deVries.)

14. "Recommendations regarding teaching helps are many and divergent." (Those favored by 60 per cent or more of the judges are "questions," "summaries," "laboratory experiments to be done," "glossary at end," and "use of a separate laboratory manual".)

STUDY NO. 180

Attitudes and Skills Essential to the Scientific Method, and Their Treatment in General-science and Elementary-biology Textbooks

By Victor L. Crowell*

Problem.—To determine (1) "some of the most important attitudes and skills involved in the scientific method"; and (2) "in what manner, and to what extent, these attitudes and skills are treated in textbooks of general science and elementary biology used in the schools of New Jersey."

* Dissertation for the degree of Doctor of Education, Rutgers University, 1936. This digest is made from a report of this study in *School Science and Mathematics*, XXXVII (May, 1937), 525–531.

Method.—"A large portion of the available literature was examined to find out what the authors of books and magazine articles on philosophy, logic, science education, and science measurement, considered to be important elements of the scientific method. These elements were utilized to prepare a list of specific attitudes[1] and skills[2] involved in the scientific method. There were 29 attitudes and 25 skills in this initial list.

These attitudes and skills were evaluated as "Important," "Of Doubtful Importance," or "Unimportant," by 64 individuals representing 49 institutions in 20 states in different sections of the United States. These judges included 58 members of faculties of normal schools, teachers colleges, and universities; one supervisor of science in a large eastern city; and five teachers of science in high schools and academies.

An analysis was made of the 13 textbooks of biology and the eight of general science which were most generally used in the schools of New Jersey, "to find out what methods were used by the authors in treating the topic of scientific method, and which of the attitudes and skills rated as most important by the jury were mentioned by the authors. In addition to these, copies of 12 new or revised editions of general-science and biology books, published in 1934 and 1935, were examined in order to determine whether or not they differed from the older books in their treatment of this topic."

"The methods used by the authors in treating the topic of scientific method were described, and a comparison was made between the rankings of the attitudes and skills treated in the textbooks, based on frequency of mention, and the ranking according to the judgments of the jury."

[1] "An attitude was defined as a state of neural readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related."

[2] "A skill was defined as knowledge of, expertness in, execution or performance."

Findings.—1. "There exists a substantial agreement among the science teachers responding to the questionnaire concerning the relative importance of the specific attitudes and skills which are involved in the scientific method."

2. ". . . the average textbook of general science or biology is very poorly organized with respect to the topic of scientific method. Although many authors recognize the importance of the scientific method, as evidenced by statements in the preface, foreword, or in a separate chapter in the book, they have done little to organize the materials in their books so that the scientific method may be readily understood and made to function in the daily affairs of the student." ". . . the more recently published textbooks of general science and biology devote more space to the scientific method than the older books do, and . . . they include such material in the body of the text rather than in prefaces and instructions to teachers."

3. The correlations between the attitudes and skills considered important by the science teachers and the appearance of these attitudes and skills in the textbooks are respectively .06 and .45. "Of the six attitudes which were rated as important by 90 per cent or more of the judges, but three appeared in the upper quarter of a table showing the attitudes ranked in order of frequency of mention in the 33 textbooks. None of these three appeared in more than 45 per cent of the books examined. These three were the attitudes concerned with carefulness and accuracy, openmindedness, and cause and effect relationships."

4. "Of the 12 skills considered important by 90 per cent or more of the judges, six appear in the upper quarter of a table showing the skills ranked according to their frequency of mention in the textbooks. Only one of these six appeared in more than 50 per cent of the books examined." Skill in observing accurately was mentioned most frequently in the 33 textbooks and was also considered the most important by the judges.

The list of important attitudes and skills follows:

Attitudes Rated Important by Eighty Per Cent or More of the Sixty-four Judges[1]

One must revise one's opinion if the evidence warrants.

One must be careful and accurate in what one does.

One's judgments must be as unprejudiced and impersonal as is possible.

Nothing can happen without a cause.

It is necessary to be systematic in the gathering and recording of data.

One must hold one's conclusions as tentative, and must suspend judgment until all available facts are secured.

Theories are often valuable because of the experiments to which they lead, even though they themselves are later disproved.

One must be slow to accept as fact such statements as are not supported by convincing proof.

One must view facts objectively.

One must be free from dogma and superstition.

The adequacy and appropriateness of one's data can be decided upon only as a result of careful reasoning.

One should rely on facts.

Man's conception of truth changes.

It is necessary to plan prior to execution.

One must recognize that all data are not of equal value.

One must test all hypotheses against all available data.

Skills Rated Important by Eighty Per Cent or More of the Sixty-four Judges

Skill in observing accurately.

Skill in recording observations accurately and orderly.

Skill in forming independent judgments based on facts.

Skill in distinguishing between fact and theory.

Skill in picking out pertinent elements from a complex situation.

Skill in recognizing errors and defects in conditions and processes.

Skill in evaluating conclusions in the light of facts or observations on which they are based.

Skill in isolating the experimental factor.

Skill in forming sound judgments concerning adequacy of data.

Skill in synthesizing, or putting together, separate facts to form a conclusion.

[1] These attitudes and also the skills that follow are listed in descending order of relative importance as determined by the respective percentages of the judges who evaluated them as important.

Skill in gathering data systematically.
Skill in planning an experiment to determine whether or not a proposed hypothesis is true.
Skill in evaluating data or procedures.
Skill in recognizing omissions or deficiencies in situations.
Skill in profiting from worth-while criticism.
Skill in forming a reasonable generalization.
Skill in arranging and classifying data in sequence and making conclusions obvious.
Skill in applying general principles to new and concrete situations.
Skill in recalling selectively items essential to a problem.
Skill in locating problems.
Skill in disregarding irrelevant facts.
Skill in directing imagination into new and worth-while channels.
Skill in using the scientific instruments common in the laboratory.

STUDY NO. 181

Teaching Units in Biology—An Investigation

By Elliot R. Downing*

Problem.—To determine "the time required to teach certain units in biology to the point of mastery."

Method.—Early in the autumn of 1928 letters were sent to 50 teachers of biology in the high schools of Illinois, Indiana, Michigan, and Wisconsin, asking them to co-operate in this investigation. Only two expressed willingness to do so. A letter was sent, therefore, late in the following summer, to 131 "superintendents of schools or high-school principals in average-sized to small cities in the same four states" asking them "to instruct their teacher or teachers of biology to co-operate in this investigation." Of these supervising officers, 18 in Illinois, 10 in Indiana, seven in Michigan, and 15 in Wisconsin agreed to do this.

"To the teacher of biology in each of the 50 schools promising co-operation, a letter . . . was sent, together with detailed outlines of the four units." Each unit had the following

* *North Central Association Quarterly*, V (March, 1931), 453–457.

organization: A statement of ultimate and immediate objectives; an introduction or preview; and instructional materials providing necessary information, directions for demonstrations, references, and questions for class discussion and for pupil study. "The purpose of the study was explained in the letter and it was further stated that each unit was organized to secure on the part of the pupils an understanding of one important principle or a group of closely related principles—such an understanding as would enable them to apply the principle to problematic situations likely to occur in life. The teacher's attention was called to problems of this type given for drill, in the unit outlines, and she was informed that the tests to be furnished would include such problems. It was explained that teaching to the point of mastery meant developing in the pupil such a grip on the principle that he could apply it."

Upon completing a unit each teacher was sent enough mimeographed copies of the test for the unit. These test papers were returned to the investigator for correction, and along with them was sent a statement of the time in minutes spent by the class in the study of the particular unit.

Of the 50 schools which had promised to co-operate, only 17 did participate in the investigation, and of these 14 taught only one unit; three taught two units; and only one taught all four units.

Findings.—1. The degree of mastery achieved in Unit No. 1 by the schools which completed that unit ranged in mean scores on the test from 48.8 per cent to 94.07 per cent. The maximum number of possible errors which could be made on this test was 20.

2. The time required for teaching Unit No. 1 ranged from 450 minutes, about two weeks' time, to 840 minutes; the average time spent on this unit in all the schools except the one which completed the unit in 450 minutes, was about six hundred minutes. "Such evidence as is in hand shows apparently that Unit No. 2 requires about the same time [as Unit No. 1];

Unit No. 3 somewhat less—perhaps three hundred or four hundred minutes; but Unit No. 4 considerably more—probably not less than six to eight weeks."

Conclusions.—1. ". . . to teach a principle of biology so that it will function in life situations requires somewhere in the neighborhood of four weeks, in which case it is evident that we may not teach more than eight or nine such in the course of a year's work, and not even that many if we are going to try to give skill in scientific thinking and establish any of the desirable emotionalized standards."

2. "The most striking feature of this study is the apparent inability of most teachers of high-school science to give pupils mastery of a principle."

STUDY NO. 182

An Experiment in the Teaching of the Principle of Photosynthesis

By Marion V. Magruder*

Problem.—To determine (1) whether the understanding of the principle of photosynthesis is affected by reducing to a minimum the structural detail now included in its development; and (2) whether the understanding of the principle of photosynthesis is affected by transferring the structural detail now included in its development, to a preceding unit, dealing with the relationship of organisms to environment.

Method.—". . . a three-way plan for teaching the unit on photosynthesis was prepared. The first, or *A*, plan presented the principle according to the District of Columbia course of study, but with only such structural detail as Downing[1] included in a similar unit. The second, or *B*, plan presented

* *Science Education*, XX (October, 1936), 146–150.

[1] Elliot R. Downing, "Teaching Units in Biology—An Investigation," *North Central Association Quarterly*, V (March, 1931), 453–470. See pp. 90–92 of this volume.

photosynthesis according to the course of study. The third, or *C*, plan presented it according to the *A* plan, but followed a unit on adaptation to environment in which the same structural detail appeared that was presented in Plan *B*. In all three plans, photosynthesis was given the major emphasis within its own unit." The same teacher prepared and taught all three plans, and every effort was made to keep constant all conditions except the experimental factor as indicated in the statement of the problem.

The experiment involved 90 pupils, mostly in the tenth-grade of the Western High School, Washington, D. C. These pupils were equated in three groups on the bases of age, I.Q., and previous semester's biology rating. "A pupil in one group paired with one in another group when the age difference did not exceed 10 months; the I.Q. not more than five points; and the previous semester's ratings were similar." From Group A, 26 and 19 pupils, respectively, were equated with equal numbers of pupils from Groups B and C; from Group C, 23 pupils were equated with an equal number from Group B.

Photosynthesis was taught to Experimental Group A in accordance with Plan *A*. The time allowed for this presentation was twenty-four 45-minute periods or about four 6-period weeks.

Photosynthesis was taught Control Group B in accordance with Plan *B*. The time allowed for this presentation was twenty-nine 45-minute periods of about five 6-period weeks. This time included the presentation, review, drill in problem solving and the two-period test at the end.

Photosynthesis was taught Experimental Group C in accordance with Plan *C*. "The time allowed for this preliminary unit and for the actual study of photosynthesis was thirty-one 45-minute periods or about five 6-period weeks."

"With all three presentations, experiments, charts, models, pocket gardens, moving pictures, etc., were used for demonstration purposes."

At the end of the presentation and review period a 65-point objective test was administered to each class in two 35-minute periods. This test had been constructed by the investigator and had been validated by the opinions of seven biology teachers. A short re-test followed a two weeks' period during which the corrected first test was discussed with the pupils and a drill in a 5-point summary of photosynthesis was given. This test was scored 15 points if perfect: one point for each of 10 true-false statements, to be corrected if false; and five for the 5-point summary of photosynthesis upon which drill had been given the previous week. The differences in means were divided by the probable errors of the differences between the means.[1]

Findings.—1. "In every case the critical ratio shows that there is no significance in the differences between the means from the first test . . ."

2. "Similar calculations for the re-test showed a similar lack of significance."

Conclusion.—1. "From this, one might conclude that the amount and placement of structural detail has little or no effect upon the understanding of the principle of photosynthesis. If this is true, the five or six additional periods needed for teaching the structure might better be spent upon some other subject matter in a crowded curriculum, unless some value other than the understanding of photosynthesis has sufficient weight to justify the time spent."

[1] Karl Holzinger, *Statistical Methods for Students in Education* (Boston: Ginn and Company, 1928), 102, 235–237.

STUDY NO. 183

Some Probable Outcomes of Partial Self-direction in Tenth-grade Biology[1]

By Wesley Converse Atkins*

Problem.—To determine whether various objectives of laboratory work in general biology, such as to effect (1) a "greater factual knowledge of subject matter," (2) a "keener interest and more painstaking effort, as shown in reports of laboratory work, or of out-of-school studies," and (3) "a more scientific attitude," are "the more successfully attained by the use of conventional methods, . . . or by the use of laboratory methods involving a considerable measure of self-direction. . ."

Method.—The first part of this investigation was conducted in the autumn of 1929, with three pairs of equated groups, two of boys who were studying the second semester's work in general biology under the investigator, at the Jefferson High School of Elizabeth, New Jersey, and one of girls who were studying the second semester's work in general biology under a woman teacher in the Battin High School of the same city. The investigation was completed during the following semester with two pairs of equated groups of boys, one of which was beginning, and the other finishing, its study of biology under the investigator in the Jefferson High School; and two other pairs of equated groups who were beginning the study of biology under two women teachers in the Battin High School.

The groups were equated on four bases: mental ability and I.Q., as measured by scores on the Otis Self-administering Test of Mental Ability, Higher Examination, Form B, and the

[1] Compare this study with that of Douglas and Fields, pp. 181–184 of this volume.

* Dissertation for the degree of Doctor of Philosophy, Teachers College, Columbia University. Princeton, New Jersey: Princeton University Press, 1936.

Chapman Unspeeded Reading-comprehension Test, Grades V to XII; chronological age; and scores on the Powers-Oakes Test of General Biology, Form A. In equating the groups on the various bases, the differences in means were divided by the S.D.'s of the differences in means. The resulting ratios were less than 1.00 except that of one group with the Powers-Oakes test, with which the ratio was 2.00.[1]

Conventional methods of laboratory work were followed in general in the control (C-) classes. In general only one double laboratory period was devoted to each topic. "The teacher read and graded all written reports and then criticized and summarized them for class discussion the following class period. Sometimes the pupils were asked to read from representative papers in order that faulty findings might be corrected and implications checked."

The time allotment in number of class periods was about the same for both groups, the C- and the Experimental (X-). ". . . when any special finding or set of findings, or any special method had been of unusual interest with the X-group it was very likely to be made use of in the C-class which followed."

"Even in C-groups the pupils did much individual experimenting and investigating, and enterprising pupils were regularly encouraged to follow their own methods, which they did on countless occasions."

"The chief difference was that C-groups were regularly held responsible for a given piece of work assigned by the teacher. Other efforts were commonly supplementary, rather than substitutional. They did not commonly choose or plan the details of their own laboratory work. In neither class was any prepared notebook used." C-groups were given mimeographed sheets of laboratory directions; "and their notebooks consisted of their written answers, drawings, et cetera. The essential characteristic of C- notebooks was that the work consisted of

[1] Henry E. Garrett, *Statistics in Psychology and Education* (New York: Longmans, Green and Company, 1926), p. 134.

answers to the teacher's questions, while those of X-groups consisted of answers to the pupils own questions . . ."

"With the X-groups a topic was regularly announced by the teacher from one to several days before time for the actual laboratory work to begin. Then from 10 to 30 minutes was usually spent by teacher and class in a joint exploration of the possibilities of the topic for class and individual project studies." Care was exercised by the teacher to insure that these projects were practicable with respect to the time and the equipment available and to the skills of the pupils, and that they "were not too simple or trivial to justify formal laboratory effort." "Usually . . . an outline was drawn upon the blackboard so that the whole class could get an idea of the possibilities of the problem as a whole. For the next day's assignment pupils were asked to bring in a written outline of the problem or problems on which they wished to work . . ." "These preliminary plans were then submitted to the teacher for criticism and approval while the class was engaged in other work; or at times the pupils were asked to read their outlines before the class while class and teacher shared their criticism." Unsatisfactory outlines were returned for revision or additions.

"In the laboratory period each pupil, under the general supervision of the teacher, proceeded to gather his materials. Often he had brought them with him; and not infrequently he was excused to go to library, cafeteria, Board of Health, parks, stores, or restaurants, to gather materials or data required."

The time for completion of the exercise was usually "extended from one to five days of class time, and over most of the accompanying homework assignments whenever it seemed advisable. On the day a topic was first explored by teacher and class, an estimate was given of the time to be devoted to that topic. Later, if interest lagged, it was sometimes found advisable to shorten the time, but much more frequently it was lengthened to permit of following up new and worthwhile leads. As close check as possible was kept on each individual's work at each

moment of the session, and at frequent but irregular intervals the attention of a small group or of the whole class was called to the findings, or exhibits of a special group, to essential modifications of method, or to further possibilities for worthwhile study."

"The day following the completion of the laboratory work . . . individual pupils in turn presented to the class the written reports of their study . . . supplemented by many oral additions in response to questions and comments of others"; or, more frequently, "the teacher led in a topical summary of the class findings . . ." "Individuals in turn gave their findings on each subtopic, and the discussion was usually prolonged to cover the whole discussion of the topic as based on textbooks, models, charts, or specimens, as well as on laboratory work. Hence almost the entire work of the semester grew out of the successive laboratory exercises; and one laboratory exercise led directly into another."

"Textbook assignments were incidental, being made more as announcements of reference material available than as exact assignments to be learned and recited upon." These assignments ". . . were followed by constructive discussions, plans for investigation, or investigation and symposium on the findings."

"Great care was used to have each X-group and its corresponding C- cover the same work, or at least to start with the same topics. As a result of the very character of the experiment, the amounts and natures of the work covered by the X- and by the corresponding C-groups varied greatly."

At the end of the semester the Powers-Oakes Test of General Biology, Form B, was administered together with the investigator's True-False Attitudes Test, and various other measures including one "designed to test the ability of the pupil to do actual laboratory work in the laboratory and knowledge gained directly through laboratory work"; and another to test the ability to investigate a simple biological problem outside the

laboratory, making use of any resources available. Coefficients of correlation computed for these various tests by the Spearman Foot-rule Method were with one exception positive but were with few exceptions relatively low.

A special study of the notebooks was made by five teachers of biology and one teacher of general science. These teachers were asked to decide with respect to which member of each pair had excelled in "range of subject matter, integration of significant ideas, vital interest, ability to question nature, and scientific attitude as evidenced by tendency to hold conclusions tentatively, weighing evidence, and knowledge of and respect for authorities." Also, a quantitative study of these same notebooks was made by the investigator in accordance with the following criteria: "clear statements of cause-and-effect relationships, grasp and understanding of other significant relationships, i.e., the ability to bring together the things which belong together, training in heredity, social hygiene, euthenics, eugenics, and references to exact sources of information as authorities."

The numbers of pupils in each pair of equated groups used for comparison with respect to these various measures varied from 12 to 20. The significance of the differences in the results of the various phases of the experiment were determined from the ratios of the differences in mean scores to the S.D.'s of the differences of these mean scores, except for the quantitative study of notebook content, the significance of which was determined in terms of the sigmas of differences.

Findings.—1. "No conclusive evidence was found that the experimental methods attempted in the foregoing studies resulted in either greater or less factual knowledge than might be expected from the use of conventional methods."

2. "When judged by the interest and effort elicited, the evidence is almost wholly in favor of partial self-direction in tenth-grade biology." The X-pupils "read far more widely and carefully" than did the C-pupils. "They seemed to learn

the joy of finding out answers to their own questions, rather than questions assigned by someone else, by both reading and by experimenting." "They showed familiarity with objects in question, resultant from independent handling to satisfy personal curiosity." "They saw more clearly the objects studied; as evidenced by voluntary drawings, both original and copied, far in excess of those made by C-students."

3. "Judged by evidences of a scientific attitude, the experimental method seems to show superior merit." The differences between the scores of the X- and C-groups had reliabilities varying from 2.0 to 4.6 sigma of difference.

Conclusions.—1. "Methods involving partial self-direction in tenth-grade biology are not impracticable; and . . . given feasible conditions, some results educationally desirable are more likely to be secured than when conventional methods are followed."

2. ". . . a combination of conventional methods in teaching general biology with a certain amount of flexibility; including much optional work, stimulation of individual initiative, and the choice of much material of immediate interest, . . . seem likely to contribute values usable in activities of the particular pupil at that particular age, and likely in turn to lead on to other wholesome and worthwhile activities of succeeding months and years."

3. ". . . the best third of secondary school pupils in biology can and will use much individual freedom of study with advantage."

4. ". . . careful conditioning of each class for a measure of self-direction should be painstakingly sought, no matter how large or how stupid the class."

5. "A limited number of individual projects is possible with all groups."

STUDY NO. 184

The Micro-projector Compared with the Individual Microscope in Teaching High-school Biology

By Allan Stathers*

Problem.—To determine whether pupils accomplish more in the study of biology through the use of individual microscopes or through the use of the projection of microscopic slides.

Method.—Two groups of high-school pupils were paired on three bases: chronological age, I.Q. on the Otis Self-administering Intelligence Test, and "average class achievement weighted by accomplishment in biology." These groups were considered to be equivalent on each of the three bases when the difference in mean scores divided by the S.D. of the difference of these mean scores was less than 1.00. These three quotients were respectively .67, .16, and .0.

"Specially designed study guides were used for both the experimental (X-) and control (C-) groups." Conditions were kept constant in the two groups "except for the method of observation of the specimen on the slide." The X-group observed the projection of the slide on a white screen; each member of the C-group observed that same slide through a compound microscope. The experiment continued for 12 weeks during which both groups viewed the same 17 slides.

Ten objective tests were constructed consisting of true-false items, and those requiring the pupils to draw and label what they had observed. These tests were administered at the end of the experiment and were scored by the instructor. All "unreliable subjects" were eliminated from the experiment, leaving 28 pairs.

* *Science Education*, XVII (February, 1933), 59–63.

The reliability of the difference in the gains by the two method was computed by dividing the difference by the S.D. of the difference.[1]

Findings.—1. All but five of the pupils of the X-group made a greater average gain on the tests than did the corresponding pupils of the C-group. Of these five, two scored zero gains. The X-group scored a total of 275 points, or an average of 10 points per pupil more than the C-group.

2. The obtained difference in mean scores divided by the S.D. of the difference of the mean scores, resulted in a quotient of 5.3, or 1.3 more than the amount indicative of complete reliability.[2]

3. The quotient of the difference between the X-score and the C-score divided by the C-score, resulted in a 19 per cent superiority of the X-group.

4. A saving of from 50 to 75 per cent of time is effected by the use of the micro-projector instead of individual microscopes.

Conclusions.—". . . even after reasonable discount, there are strong implications for the use of the micro-projector as an improved teaching device over the individual microscope for high-school pupils. A correct detailed observation with group discussion under the direction of the instructor prevails."

[1] $\text{S.D.D.} = \sqrt{(\text{S.D.M.}_1)^2 + (\text{S.D.M.}_2)^2 - 2r(\text{S.D.M.}_1) \cdot (\text{S.D.M.}_2)}$.
Helen M. Walker, "Concerning the Standard Error of a Difference," *Journal of Educational Psychology*, XX (January, 1929), p. 54.

[2] Henry E. Garrett, *Statistics in Psychology and Education* (New York: Longmans, Green and Company, 1926), p. 133.

STUDY NO. 185

The Newspaper as Source Material in Health Education[1]

By Sally E. Kutz*

UNIT I

Problem.—To evaluate the extent and the nature of material on public health and hygiene appearing in three selected newspapers, as news, editorials, and advertisements; and to consider the values and the methods of using this material in teaching public health and hygiene in college

Method.—The materials analyzed in this investigation were published in three daily newspapers, the *New York Times*, the *Morning World*, and the *Evening Graphic*, during the 50 weeks from September 2, 1929 through August 9, 1930. In all there were 240 different issues of these papers (84 copies each of the *New York Times* and of the *Morning World*, and 72 copies of the *Evening Graphic*), which together contributed 4,364 items: 1,536 news articles, 122 editorials, and 2,706 advertisements. The column inches of this material totaled 20,292.5.

The papers were thoroughly read, column by column. All articles and advertisements selected for analysis were checked with a red pencil. A check-mark placed at the top of each page containing such an article facilitated locating these articles for subsequent clipping from the papers. Every doubtful item was indicated by a question mark, and, like the others, was clipped, and reserved for further study. The

[1] See also studies of health materials by Strang, Lerrigo, Cairns, Meier, and Chappelear, *Investigations in the Teaching of Science*, Vol. II, pp. 52–56, 164–168, 169–173, 173–177, and 177–186, respectively.

* Unpublished dissertation for the degree of Doctor of Philosophy, New York University, 1932.

articles were selected on the bases of one or more of these criteria:

They must include material on hygiene, as judged by the opinion of the investigator based on her knowledge of hygiene.

They must treat of topics included in standard texts on public health and hygiene.

They must treat of subjects included in three courses in general hygiene and public health offered in Brooklyn College.

"All articles which had a health implication were included as well as pertinent advertisements."

Each article clipped from one of the issues of these newspapers was marked with the name and date of the paper from which it had been taken. It was then inserted in an envelope, and on the outside of the envelope, in a column at the left-hand side was written the name of the newspaper, the date, the day of the week, the number of pages in that issue of the paper, the page on which the article appeared, the column number, the column position (top, middle, or bottom), the number of column inches as measured by a foot rule, a notation of whether the article was illustrated or not, the section of the paper in which the article appeared, and the number of pages in the section. At the top right-hand side of the envelope, the item was classified as news, feature, editorial material, or advertisement. Under its classification was placed the subject of the article. Where more than one topic was discussed in the same article, the one receiving the most emphasis was taken as the basis of classification. In the cases in which several paragraphs relating to health problems appeared under different headings, the topic of each paragraph was recorded separately.

"The clippings from each paper were fastened together according to days, and these in turn according to weeks. The envelopes for the three papers were filed separately. The Sunday clippings were kept separate from those of the weekdays."

The clippings were sorted in three groups, news, editorials, and advertisements, and were arranged according to day, month, and paper. "Each envelope was given a serial number. Any article about which there had been doubt was re-read, and every item was tentatively classified."

Articles and advertisements were measured—including illustrations where these occurred—and the length to the nearest half inch was recorded. In the final analysis, however, "the unit of comparison was the number of articles, rather than the number of column inches."

Findings.—"In some articles publicity was given to meetings and conferences, to awards of prizes for distinction in health activities, and to the openings of hospitals and health centers. In others, propaganda sought to arouse interest in campaigns against noise, smoke, quacks and anti-vaccination movements; or proposed sanitary improvements, legislation in favor of old-age pensions, or the erection of more hospitals. Some of the articles made their approach through Public Education, i.e., articles on diet, care of the teeth, yearly physical examinations, the importance of vaccines in certain diseases and the value of recreation."

Tables LXXXIV and LXXXV present the aspects of health education most frequently referred to in the articles, editorials, and advertisements analyzed.

UNIT II

Problem.—To determine the extent to which "the average person is interested in reading news on public health and hygiene appearing in newspapers."

Method.—A group of 120 individuals representing a random sampling of friends and students of the investigator were asked to check the articles which they read in the papers during a period of one week. They were asked not to mark an article as read unless they had read the headlines and at least the first paragraph. Only 66 returned enough material to be analyzed.

TABLE LXXXIV

NUMBERS OF ARTICLES AND EDITORIALS DEVOTED TO VARIOUS TOPICS OF HEALTH EDUCATION

Topics	Number of articles	Number of editorials
Safety	161	18
Recreation	60	12
Personal hygiene	60	9
Sanitary nuisances	69	9
Forests	38	8
Hospitals	96	7
Medicine and surgery	108	7
Disposal of wastes	45	6
Food and nutrition	93	6
Health administration	36	5
Vital statistics	34	5
Exercise and fatigue	135	4
Personal defects	18	4
Sex	17	4
Alcohol	36	3
Child hygiene	55	3
Communicable diseases	110	3
Miscellaneous	17	2
Health education	68	1
Housing	11	1
Longevity	14	1
Non-medical practice	29	1
Physical culture	38	1
Water	21	1
Non-communicable diseases	38	0
Droughts	12	0
Eugenics	8	0
Floods	12	0
Industrial hygiene	10	0
Mental hygiene	51	0
Old age	16	0
Ventilation, heat, and lighting	20	0

Findings.—1. "There were 2,222 articles in the 226 papers studied; of these, 739 articles, or 33.3 per cent, were read."

2. "Studies of readers' interest indicated that health news is not widely read."

TABLE LXXXV

NUMBERS OF ADVERTISEMENTS DEVOTED TO VARIOUS TOPICS OF HEALTH EDUCATION

TOPICS	NUMBER OF ADVERTISEMENTS
Alcohol cures	9
Appliances for physical defects	61
Cosmetic preparations	1,038
Clothing	17
Deafness	58
Epilepsy cures	18
Feminine hygiene	17
Food and beverages	132
Health examinations	280
Health resorts	14
Hernia	65
Household sanitation	40
Kidney remedies	22
Non-commercial	11
Nostrums for gastro-intestinal disturbances	186
Nostrums for respiratory disturbances	179
Obesity cures	153
Pain killers	97
Panaceas	92
Remedies to increase weight	20
Tobacco	83
Treatments	44
Varicose veins	34
Miscellaneous	36

UNIT III

Problem.—To learn from students and teachers their opinions of the value of the newspapers in the study of hygiene.

Method.—A questionnaire containing seven questions designed to elicit the information desired, was distributed to

69 students who were studying advanced courses in hygiene. A similar questionnaire was distributed to 14 college teachers of hygiene.

Findings.—1. Of the students, 94 per cent stated that they found the newspapers of great value to them in the study of hygiene because reading newspapers "enabled them to keep up with current information in the varied fields of public health and hygiene, and thus supplemented material in textbooks; . . . it aroused interest in new problems, made them more observant, developed civic pride, correlated the subject of hygiene with life situations, and developed the habit of newspaper-reading."

2. Of the college teachers of hygiene, 14 stated that they found newspapers valuable in their teaching, because the newspapers made current information immediately available; because newspapers "printed news of proposed legislative changes and new enactments, and published notices of changes in the personnel of health departments and health organizations; because newspaper clippings formed a basic part of a library of ephemeral literature; and, lastly, because the newspaper helped to vitalize the subject of hygiene, thus enabling teachers to arouse their classes to a greater interest in that subject."

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STUDY NO. 186

Study Outlines in Physics—Construction and Experimental Evaluation

By Jessie Williams Clemensen*

UNIT I

Problem.—To construct Study Outlines to be used as assignment sheets in the teaching of physics.

Method.—The investigator first secured a list of objectives for the course in high-school physics and of specific subject-matter items by which these aims might be developed, by analyzing (1) professional literature on educational philosophy, curricula, and methods; (2) popular scientific periodicals and three popular scientific books; (3) texts available at the time (1927); and (4) "questions and projects suggested spontaneously during six previous semesters by high-school physics

* Dissertation for the degree of Doctor of Philosophy, Contributions to Education, No. 553. New York: Teachers College, Columbia University, 1933. A brief account of this study appears in *Science Education*, XVI (December, 1932), 453–461.

pupils in the investigator's own classes." These objectives furnished the basis, and the subject-matter items the materials, for the construction of Study Outlines designed for teaching the entire course in high-school physics.

The technique of constructing the Study Outlines consisted of the following steps:

1. The selection of eight convenient units reasonably consistent with the high-school physics course of study, texts, and manuals.
2. The analysis of each unit into its main ideas or concepts, and the formulation of problems for the developing of these concepts.
3. The tabulation, under each problem, of its subject-matter items and their general aims as listed in the objectives.
4. The formulation of these subject-matter items into direct questions, each as nearly as possible containing "one idea," parallel ideas being given parallel placement in the Outlines, so as to show their relationship to one another and to the main concept being developed. These questions were worded and arranged so as to develop interests, attitudes, and habits as well as concepts, knowledges, and skills.
5. The compilation of references to the pupils' texts and other standard texts for each problem.
6. The mimeographing of the Outlines and binding them to fit the pupils' laboratory notebooks.

Most of these Outlines were subsequently revised extensively, as experience in using them revealed weaknesses in them.

The following is a sample of Study Outline problems:

Problem 6. (Buoyancy) Under what conditions will anything float?

a. Why can a steel ship weighing thousands of tons float?
b. Does a ship float higher in salt water or fresh water? Why?
c. Even though a body does not float, is it buoyed up any (i.e., apparently made lighter) by being submerged in a liquid? Have you ever lifted a stone under water? Was it easier or more difficult than in air? Why?
d. What determines the amount by which a body will be buoyed up by a liquid? How many things count? Why?
e. What is meant by the "specific gravity" of a liquid? How is this commonly used? How is it measured?

References: (These are given by page and section for several common texts).

UNIT II

Problem.—To determine the values of these Study Outlines when used as assignment sheets in regular classes of high-school physics.

Method.—The Study Outlines constructed in Unit I were used during one semester, in an investigation with 850 pupils. These pupils were studying physics under 17 teachers in nine high schools of Los Angeles, California. The classes that participated were organized in three groups: Group I (the "Outline" group) was composed of three first-semester classes and four second-semester classes, all taught by different teachers, but all using the Study Outlines for home-work assignments; Group II (the "Non-Outline" group) consisted of one first-semester and four second-semester physics classes; and Group III (the "Outside-Control" group) was made up of four first-semester and six second-semester classes taught by superior teachers of physics who knew nothing about the Outlines. Comparable groups were obtained by means of predicted scores obtained with a regression equation worked out by multiple correlation of final objective-test scores with initial scores on four tests: (1) scores on a test of information invented by the investigator; (2 and 3) scores on the algebra and geometry sections of the Kirby-Kilzer Inventory Test for the Mathematics of High-school Physics; and (4) the I.Q.'s. The final measures used were (a) scores on a series of objective tests administered during the semester; (b) scores on both forms combined of the Harvard Tests in Elementary Physics; and (c) teachers' marks for the semester.

By use of the regression equation, "a final score was predicted for each pupil on the basis of his several preliminary scores." Classes within Groups I and II were paired pupil-by-pupil according to these predicted scores. Pupils of Group

III were equated with the two paired groups within Groups I and II by taking a random sample from all classes in such a way as to make as nearly equal as possible the means and the S.D.'s of the three resulting groups, and at the same time so as to keep the mean and the distribution for each class practically equal to that of the large group of which it was a part. "In this way the three comparable groups were obtained—'Outline,' 'Non-Outline,' and 'Outside-Control.'"

During the last three days of the experimental semester all classes were given three types of final measures each of which required about thirty-five minutes: (1) a standard new-type objective test in high-school physics; (2) a final essay test covering the whole course; and (3) a questionnaire on specific habits and attitudes. Besides these, four smaller topic essays were required of the paired classes of Groups I and II during the semester. Also all the participating teachers and pupils filled out a questionnaire which was intended to reveal their attitudes toward the Study Outlines themselves, and to indicate the extent to which the pupils of the various "Outline Classes" had really used the Outlines.

The significance of the results with the objective tests was obtained by dividing the differences in mean scores by the standard deviations of the differences of those mean scores.

The four topic essays consisted of such items as this, "Tell all you can in 15 minutes about atmospheric pressure—experiments concerning it, applications, etc." The papers were analyzed for concepts expressed. "The method used was similar to that used by Black.[1] Each statement on each paper was copied on a card. The cards were then sorted and classified according to the types of ideas expressed."

In the final essay test the pupils were asked to "write a summary of the outstanding principles, facts, and ideas of the semester's work." "In analyzing these tests, each statement was underlined with a colored crayon, a different color

[1] *Investigations in the Teaching of Science*, Vol. II, pp. 239–246.

being used for each type of statement, such as: general principle or law, application or illustration, descriptive explanation, causal explanation, mere statement of fact, and mere reference to a topic. In addition, erroneous, inaccurate, incomplete, and vague statements of each type were marked in the margin. The number of statements of each type was then tabulated for each paper and totaled for each group."

The check-questionnaire contained "23 specific items concerning methods of study." The reactions to these questionnaires were presented in 46 charts.

Findings and Conclusions.—1. "The entire consistency of all results of the experiment is unusually strong evidence that the [use of the] Study Outlines produced real and measurable differences. The objective tests revealed the superiority of every one of the small 'Outline' groups over its paired 'Non-Outline' group of the same teacher. Even greater differences than these were shown" between the "Outline" group (Group I) and the "Non-Outline" group (Group II); and between the "Outline" group (Group I) and the "Outside-Control" group (Group III).

2. In the topic essays, the "Outline" groups in comparison with the "Non-Outline" groups (a) "made a greater total number of statements," i.e., "had more ideas associated with the topic"; (b) "attempted to explain nearly twice as large a percentage of their statements"; (c) "made nearly two and one-half times as many causal statements in their attempted explanations"; (d) "made a smaller percentage of incomplete, vague, and erroneous statements"; (e) "made more statements which indicated a grasp of larger generalizations"; (f) "made three times as many unusual and non-text references"; and (g) made a smaller percentage of statements of minor details and isolated facts.

3. The final essay tests showed "much the same results as were noted for the topic-essay tests."

4. The results of the questionnaire showed a "consistency of the differences in favor of the 'Outline' groups over their paired 'Non-Outline' groups and 'Outside-Control' groups, with the exception of a few items where the differences are negligible." The better study habits of the "Outline" groups, as indicated by the data from the complete questionnaire, are: "to relate the lesson to previous ones, to skim the lesson first to formulate questions about it; to study diagrams carefully, to determine reasons for text statements, to supplement the text with original examples, to relate the lesson to things outside of class, to get a bird's-eye view of the lesson, and to outline the subject for review."

5. "Two questionnaire items showed beyond doubt that the 'Outline' pupils felt more interest in the study of physics and felt a greater sense of satisfaction with the course than did either of the other groups. This indicated that most physics students appreciate learning something in an attractive, organized manner rather than merely being entertained.'

STUDY NO. 187

The Optimal Teaching Sequence for Elementary Physical Principles Based on a Composite Scale of Pleasure-value and Difficulty of Insight

By George W. Hartman* and Dean T. Stephens

UNIT I

Problem.—To determine the relative difficulty of principles of elementary physics, and of the five main divisions of physics.

Method.—An analysis was first made of the six most commonly used high-school textbooks of physics to segregate

* *The Journal of Educational Psychology*, XXVIII (September, 1937), 414–436.

"all discriminable principles, laws, corollaries, and 'key' phenomena." From these books 263 separate principles[1] were secured. The list of principles was reduced by eliminating both those that did not appear in all six texts, and those that, in the judgments of four physicists, were either duplications or closely related statements. The resulting list of 144 principles of physics included 38 for *mechanics*, 19 for *heat*, 50 for *electricity*, eight for *sound*, and 29 for *light*.

A test to measure the relative comprehension difficulty of these principles was prepared by making five questions designed to test understanding of each principle. Practically all these questions were carefully formulated from recent texts. They were selected on the basis of the results of a preliminary trial conducted during the school year of 1934–1935 with a group of pupils different from those used subsequently, but comparable with them. Questions that no pupil answered correctly in this preliminary trial were omitted from the subsequent inquiry, "although for motivation purposes as well as because of their undeniable basic importance, a fair number of those that everyone got right were retained." The questions retained for each principle ranged from easy to difficult. The arithmetical ability involved in those questions demanding numerical solutions "was kept at a minimum so that different degrees of mathematical competence would not affect the apparent understanding of a basic physical principle."

During the school year 1935–36, 12 pupils enrolled in the junior author's class in high-school physics, and having I.Q.'s ranging from 120 to 142, were examined "regularly, individually and intensively" by means of the test just described. It was assumed that the order of difficulty of principles of physics, established for superior students is probably the same as that for average and inferior students. "Instructional

[1] "A principle was conceived as a functional relation or 'whole' involving the interconnection of two or more concepts."

emphasis was kept as nearly constant and uniform for all parts of the course as the mild oscillations in the classroom teacher's psychophysical tone allowed." A "difficulty score" was computed for each principle by adding together the numbers of correct answers which the 12 pupils gave to the five application questions for the item. Only entirely correct answers were accepted. The percentage this total was of the highest possible total (60) was called the "difficulty index" of the principle. The mean "group insight," or mean percentage score of the 12 pupils, was determined for all the principles in each of the five main divisions of physics, *mechanics*, *heat*, *light*, *sound*, and *electricity*.

Findings.—1. The "difficulty indexes" for the 144 principles ranged from 99.16 to 50.00 per cent.

2. The mean "group insights" for the principles of *heat*, *mechanics*, *light*, *sound*, and *electricity* were, respectively, 88.72, 86.18, 83.21, 80.10, and 78.56 per cent.

UNIT II

Problem.—To determine the relative "pleasure values" of principles of physics.

Method.—The principles printed in a booklet in such an order that a large number belonging to one of the five major divisions of physics did not appear together, were submitted, as a Pleasure-Aversion Test, to 252 pupils who had just completed a year's work in elementary physics. These pupils represented six Pennsylvania cities and included 107 Junior boys, 58 Junior girls, 71 Senior boys, and 16 Senior girls. These pupils were asked to indicate in the appropriate column opposite each principle whether they felt an extreme, a moderate, or a slight aversion or pleasure toward each principle, or whether they were neutral or indifferent to it. The pupils began at different points on the list "to prevent a possible reduction of reliability caused by a concentration toward the end of a number of unfinished items" and to

avoid "stereotypy of response" by thus "distributing the fatigue factor." Numerical equivalents were assigned to each response as follows: pleasure—extreme (3), moderate (2), slight (1), neutral or indifferent (0); aversion, slight (1), moderate (2), and extreme (3). "The mean pleasure value of each principle was calculated readily by summing algebraically its rating in all papers and dividing that total by the number of persons answering the item."

Pearson product-moment correlations were computed between mean pleasure values and difficulty (as determined in Unit I) of the various items. The consistency of the Pleasure-Aversion Test was determined by pairing scores from two sets of 75 papers each, selected by taking a boy's and then a girl's paper from each school in rotation. From these two groups, two independent sets of mean scores were obtained for each item and these were correlated. The *grand* mean pleasure value of the 72 odd items for each of the 252 subjects was also correlated with the corresponding quantity for the 72 even items.

A comparison of the mean pleasure values, or "pleasure indexes," of boys and girls was made with the values derived from a sample of 50 boys' and 50 girls' papers.

Findings and Conclusions.—1. The mean pleasure value for all the principles was .94 ± .035. The range was between 1.931 and 0.064.

2. "The descending order of the mean pleasure indexes for the different physical divisions ran as follows: *light*, 1.101; *mechanics*, 1.054; *heat*, 1.007; *sound*, 1.004; and *electricity*, .718.

3. The coefficients of correlation were sufficiently high to indicate a satisfactory degree of reliability for the Pleasure-Aversion Test.

4. "There are noticeable differences in the mean pleasure indexes in the population of the various schools."

5. The chances were found to be 99.63 in a hundred that the pleasure value of boys is greater than that of girls, and

supports "the common claim that in our culture physics appeals more to one sex than to the other."

6. The pleasure value of short-sentence principles was greater than that of statements of more than average length.

UNIT III

Problem.—To construct a combined learning scale for the physical principles on the basis of both pleasure and difficulty values; and thus to determine "an order of exposition adapted to the developmental peculiarities of the average student of high-school physics."

TABLE LXXXVI

PRINCIPLES OF ELEMENTARY PHYSICS IN THE ORDER OF THEIR COMBINED INDEXES BASED UPON THEIR RESPECTIVE INDEXES OF DIFFICULTY AND OF PLEASURE VALUE

Principle	Combined index	Rank	Index of difficulty	Rank	Index of pleasure value	Rank
Mechanics						
Energy can never be created or destroyed; it can be changed from one form to another with exact equivalence	199.10	1	99.16	1	1.930	1
Gases tend to expand and completely fill their containers	178.85	2	98.33	2	1.555	4
Disregarding friction, the work put into a machine is equal to the work gotten out of it	178.88	3	99.16	1	1.501	5

Method.—A "combined index" was obtained by adding the index of difficulty of each item (from Unit I) to the product of the pleasure value (from Unit II) and the quotient obtained by dividing 100 by 1.931 (the maximum pleasure value obtained for any of the items). The principles were then arranged in descending order of their combined indexes within each of the five main divisions of physics, namely *mechanics*, *heat*, *light*, *sound*, and *electricity*.

Findings and Conclusions.—The mean combined indexes for the principles of *heat*, *mechanics*, *light*, *sound*, and *electricity* were found to be, respectively, 140.91, 140.78, 139.93, 132.10, and 115.74. The only completely reliable difference is between the *electricity* section and the others, although the chances of a significant difference for the *sound* category (in all pairs other than *electricity*) run about 97 in 100.

A sample of the final tables is given in Table LXXXVI.

STUDY NO. 188

A Critical Analysis of Pupil Responses to the Concepts of Mechanics in High-school Physics

By Phillip M. Bail*

Problem.—To determine (1) "the efficiency of learning as it is now being carried on; (2) to locate the dominant errors made by pupils in exercises based on the concepts of *mechanics*, and (3) to analyze the processes by which pupils arrive at these dominant errors."

Method.—An analysis was made of 12 sources of physics content, which included four textbooks, four courses of study, and four research studies, in order to select the fundamental

* Dissertation for the degree of Doctor of Philosophy, State University of Iowa, 1931. This digest is made from a report of this study in *Science Education*, XVII (October and December, 1933), 226–232 and 321–329.

concepts[1] to be used in the construction of the drills. Of the concepts thus obtained, 152 were selected as valid on the basis of the judgment "of an expert in physics."

"The mechanics drills were constructed according to a definite pattern in order that the various concepts might be presented to the pupils in different situations as well as at repeated intervals." The formulas to be used in the drills were validated by means of textbook analysis. The technical vocabulary used in constructing the drills was selected from the vocabulary list for physics, by Pressey,[2] and the list of scientific terms by Frank and White.[3]

The types of items used in the different drills included completion, matching, multiple-response, one-word, numerical problems, diagrams, and a modified true-false in which the false items were corrected.

The investigation included 25 series of drills, including 8,127 separate drills involved in 246,379 different exercises. These exercises were performed by approximately twenty-one hundred pupils in 43 school systems of varying sizes located in 14 states. "Every exercise in each drill was marked *R*, *W*, or *O* according to whether it was right, wrong, or omitted. The data were tabulated with Hollerith tabulating machines."

Reliability coefficients of the entire 25 drill series were computed on the basis of responses on the odd-numbered and the even-numbered items; and Brown's Formula was applied to these results in order to determine the reliability of each whole series. These reliabilities ranged between .66 $\pm$ .02 and

[1] "A fundamental concept in this investigation is defined as a definition, principle, law, or fact which comprises a complete idea of some physical phenomenon."

[2] Luella Cole Pressey, *The Technical Vocabularies of the Public School Subjects*, No. 10 (Bloomington, Illinois: Public School Publishing Co., 1924).

[3] J. O. Frank and H. K. White, *High School Science Terminology*. Published and distributed by J. O. Frank, State Teachers College, Oshkosh, Wisconsin.

.85 ± .01. The "index of goodness" for each series was determined by finding the ratio between the total respective numbers of errors made on the exercise by the pupils of the upper quartile and pupils of the lower quartile. These indexes were relatively high though widely variant; 50 per cent were above 3.00. The drills were analyzed for dominant errors and processes used by the pupils in arriving at each wrong response; also the hundred most difficult exercises were determined both by taking the per cent of error based upon the attempts, and by computing the per cent of error based upon the total of wrong responses plus omissions.

A further comparison was made of the average score earned on each drill by the pupils using each of the four different textbooks. The reliability of the averages was computed for the 25 drill series for each textbook by dividing the differences in means by the S.D.'s of the differences of the means.

Computations of the averages made on each drill by the pupils in each of the 43 experimental schools were made, together with composite T-scores based upon the number of pupils taking each drill in each school. "By means of these composite T-scores the variability of the schools on each drill was ascertained."

Findings and Conclusions.—1. None of the textbooks used by these pupils apparently affected the achievement more than did any other.

2. ". . . in general, one can say that the achievement in one state compares favorably with that in another."

3. The efficiency of learning in *mechanics* is very low as shown by this investigation. "Of the total 895 exercises or parts of exercises, 561 (62.6 per cent) had a per cent of error of 50 or more; and 293 (32.7 per cent) had a per cent of error of 75 or more."

4. "Even though there were many different wrong responses recorded to a large majority of the exercises, for 42 per cent of the exercises there were dominant errors which comprised a

large per cent of the errors made to that particular exercise."

5. "The pupils exhibit practically complete confusion on those exercises which do not have dominant errors but which have a high per cent of error. Pupils have many misconceptions which deal with mechanics and measurement."

6. Specific reasons for pupil difficulties were found to be (a) inability to make very simple numerical computations; (b) inaccurate knowledge or lack of knowledge of the metric units; (c) inability to use fundamental processes correctly, to analyze the problems, and to state the units in which the answer is to be expressed; (d) inability to convert metric units into British units and *vice versa;* (e) failure to apply laboratory or past experience to the solution; (f) lack of knowledge of what certain constants or approximations of constants express; (g) inadequate knowledge or lack of definite understanding of the meanings of specific physical terms and principles; (h) inability to identify the discoverer of a law with the law.

STUDY NO. 189

Co-operative Experimentation in Materials and Methods in Secondary-school Physics

By Archer Willis Hurd*

UNIT I

Problem.—To analyze and summarize the results of earlier studies by the investigator, in order to determine a basis for further investigation.

Method.—The investigator assembled the results of a large number of investigations which he had conducted during the

* New York: Bureau of Publications, Teachers College, Columbia University, 1933. The data and discussions in this monograph are supplemented extensively in a second monograph, *An Experiment in the Use of a Teaching Unit in Science* (New York: Institute of School Experimentation, Teachers College, Columbia University, 1933).

period from 1923 to 1931, and summarized their important findings.

Conclusions.—1. "Achievements measured by a series of objective tests in physics, show fairly high correlations with intelligence quotients."

2. "The following coefficients from one school show how objective-test marks in physics correlate with school marks in other courses, in descending order of rank: mathematics, .73 ± .03; English, .59 ± .05; general science and biology, .47 ± .08; history, .44 ± .08; industrial arts, .37 ± .09."

3. A series of case studies conducted for a school year in one school indicated that superior achievement in physics results from "mental ability coupled with a driving force showing itself in concentrated application, with an attendant feeling of satisfaction."

4. "In one school a 'topical' method of presenting subject matter showed significant superiority to a 'problem' method when information test scores were the criteria of achievement. The latter method was superior to the former when problem test scores were the criteria."

5. "Certain pupils in high-school physics classes may safely be allowed to plan their own lesson assignments after a term's work in the regular class. The criteria to be used in choosing such pupils are: I.Q.'s, previous grades in the subject, and teachers' ratings of the trait of industry."[1]

6. "The amount of time spent in the classroom may be lessened without appreciably decreasing measured achievements. Conversely, an increase in time spent in the classroom does not *necessarily* increase measured achievements."

7. Methods used by one teacher during different years on the same part of a course in physics, in which the same objective tests, measuring extent of information and problem solving, were made the criteria of achievement, rank as follows: textbook-recitation method; individual-project method; problem method; topical method.

[1] Compare this conclusion with those of Atkins, p. 100 of this volume.

8. "There are indications that the individual-project method tends to develop traits of industry and initiative which are not revealed by the usual objective-test marks."

9. "An overwhelming majority of writers who suggest inadequacies in the teaching of high-school science agree that the greatest need is a reorganization of content or subject matter to meet the needs of the pupils enrolled."

10. "The pupils taking courses in high-school physics vary widely in capacity, interest, vocational expectancy, chronological age, character-trait ratings, marks in previous school courses, year in school, time available for school work, number of previous sciences studied, and home environment. One course will not fit the needs of all, unless the course is planned to care for these individual differences."

11. "In a preliminary physics test taken by students entering college, those who had had a previous course in high-school physics were immensely superior. However, their later grades in college physics courses were not significantly different."

12. "Introductory courses in college physics are often markedly different from high-school courses. Apparently the best preparation for most of these college courses is a thorough study of formulae, which will develop great facility in working with formulae."

13. "Student achievement in high-school physics is much less than is commonly supposed, but test scores show that very distinct gains follow a period of instruction." "Definite remedial instruction based upon analyses of errors greatly increases pupil achievement scores."

14. "The range of objective-test scores is commonly greater after instruction than before. Instruction, therefore, makes for less homogeneity rather than greater."

15. "Students in physics classes who have studied general science do not show superiority over other students except in those parts of the course which are similar in content."[1]

[1] Compare this conclusion with that of Carpenter, p. 69 of this volume.

16. "There is much evidence that the present year's course in physics common to most schools has too much content, if previous achievement is to be increased in objective tests now used." "Instruction should probably have for its objective the mastery of a few intensive teaching units, rather than of the whole subject of physics."

17. "Definite and concise statements of *immediate* and *ultimate* objectives help greatly as criteria for selecting subject matter." "Careful planning of instructional procedures designed to accomplish the chosen unit objectives results in commendable achievement ratings above the normal."

18. "Score distributions on preliminary test items [on the minimal essentials of] a teaching unit should probably be fairly well concentrated near the bottom. For the final test, they should probably be well concentrated toward the top. Gains should be definite."

19. "Efficiency of instruction in essential concepts should probably be judged largely from distributions of test scores on minimum essential [or mastery] tests." Such tests "should receive considerable attention in instruction. Most discussions of school tests do not distinguish minimum essential tests."

20. "Preliminary tests covering the same content as final tests prove the best single criterion of achievement, but they are of little prognostic value in classes where minimum essentials are well mastered during the course by all pupils."

21. "Test types of the objective sort for use in physics rank in the following order of validity from best to worst: short-answer, uncompleted-statement, multiple-choice, true-false."

UNIT II

Problems.—To determine (1) the values of "an individual plan of instruction, based upon the analysis of pupil responses to preliminary test items, for learning of the unit elements," and (2) the values of "desirable supplementary activities."

Method.—This investigation, which was the fifth in the series, each occupying a school year, involved an experimental (X-) group of 949 pupils in 44 classes in 24 high schools, and a control (C-) group of 377 pupils in 19 classes in 10 high schools. The teaching unit[1] used was "a revision of several previous editions" and stressed "functional knowledge likely to be used often." The unit was first carefully outlined, then text materials and work-sheets to accompany them were prepared and printed. Preliminary and final short-answer tests, each of 105 items covering the minimal essentials and designed to measure information, appreciation, and problem solving, were provided. The reliability coefficient of each of these tests, corrected by the Spearman-Brown Prophecy Formula, was .980 ± .006. The validity of each of these tests was high because of (1) "parallelism between unit outline, unit text, work-sheets, and preliminary and final tests; (2) gain made after a period of instruction; and (3) gain in percentage of correct responses during the instructional period."

The printed teaching unit included the following study helps: "a carefully selected list of reference books, booklets, and periodical articles; suggested apparatus and supplies; suggestions for laboratory experiments; and suggestions for specialized activities or projects." These specialized activities or projects included making study or investigation without reports; writing papers or themes; working problems; engaging in field trips with or without reports; performing demonstrations before the class; reading books, magazines, or newspaper articles; reporting to the class an experiment not demonstrated; experimenting, constructing, drawing diagrams, keeping scrapbooks or collecting clippings; making photographs or blueprints.

[1] "The term, 'teaching unit,' is here meant to be a coherent body of subject matter bearing upon a definitely stated topic, and planned to develop clear comprehension of the elements of the topic. These elements are to be thought of as minor subdivisions which contribute to the major topic."

The investigation occupied eighteen 45-minute periods. The classes of the X-group followed this plan: During the first period, the preliminary test was administered. The second period was devoted to a discussion of the project program; each of the pupils selected a project to occupy both his class time, when he had completed his work-sheet activities, and his out-of-class time, which during the entire experiment totaled about 450 minutes. The third to the twelfth periods, inclusive, were devoted to discussing the preliminary-test papers, carrying on the work-sheet exercises, and carrying on projects. About one-tenth of the entire unit was covered in each of these 10 class periods. The work-sheet activities were completed by the end of the twelfth period. During the first part of the thirteenth period, the pupils wrote out lists of points which they would like to have explained. During the remainder of that period and through the seventeenth period, activities were carried on which were designed to clear up difficult points. These activities included lectures, experiments, demonstrations, discussions, drills, quizzes, and a final discussion of the preliminary test. The eighteenth period was devoted to the administration of the final test.

Of the schools of the C-group, a few followed the general plan adopted for the X-group but "used the teachers' outline, work-sheets, and tests supplied for the same teaching unit for the experiment of 1930–31," that is, they covered the same ground as did the X-group but used different materials. The remaining schools of the C-group made no effort to follow any of the procedures of the X-group; they did, however, cover the same ground in the same time and gave the same tests. It will be noted that only the X-group used the work-sheets and engaged in the special activities.

Results were measured in terms of means and S.D.'s of class scores, in percentages of correct responses, and in gains from the scores on the initial and final tests. Critical ratios were computed for these various measures. The project program of

the X-group was evaluated merely in terms of the numbers of pupils who engaged in the various projects.

Findings and Conclusions.—1. "Concentrating attention on securing high final scores on minimum-essential tests, and making plans therefor, pays dividends in pupil achievement."

2. "Remedial instruction, based upon a study of pupil responses to items in a preliminary test is a valuable plan of teaching."

3. "The printed unit text . . . seems to be an important feature, contributing to achievement in subject matter not included in regular textbooks."

4. The X-schools as a group "far surpassed the C-schools, when measured by the means of class scores in the final test and by gains from preliminary to final tests. The unit content and experimental plan employed are practicable and resulted in increased pupil achievement."

5. "Provision for specialized activities or projects is a workable method of caring for individual differences, and in this experiment resulted in much desirable activity and many concrete evidences thereof."

6. "The idea of establishing minimum essentials as used in this experiment is feasible and resulted in commendable achievement."

7. "Great ranges in achievement in various experimental schools indicate that the teacher is a very important factor in pupil achievement."

8. "Minimum-essential final-test distributions do not resemble normal distributions as shown by the normal curve."

9. "Evidence from these experiments favors classes in physics of fewer than 20 pupils, if high achievement is a specific objective. Also, classes of from 20 to 30 showed higher achievement than classes of more than 30."

STUDY NO. 190

The Extent of Rote Learning in Certain Units of High-school Physics

By Alvin William Schindler*

Problem.—"To secure a quantitative description of the extent to which pupils in high-school physics memorize textbook statements without grasping their meanings or developing understanding of related phenomena."

Method.—Statements of facts or principles in the subject matter of heat and electricity were selected from six textbooks of high-school physics on the basis of the following criteria:

Each statement of fact should make a definite contribution toward the achievement described by the objectives of instruction in high-school physics; that is, an understanding of the statement should result in a more intelligent attitude toward some significant aspect of the physical environment

Most of the statements selected should appear in italicized or in boldfaced type

From each unit of subject matter involved, enough statements should be chosen so that the test will provide a fairly intensive measure of the achievement in that unit

Two types of test items, Type A and Type B, were constructed. Type A possessed these characteristics: Some items required the pupil to recall and to reproduce a textbook statement; others (direct questions) required the pupil to supply a single word or a number which he recalled in a textbook statement; certain ones required the pupil to select in a multiple-response item, the correct statement of a fact; certain others presented an incomplete textbook statement which the pupils were required to complete by supplying the missing word or

* Unpublished dissertation for the degree of Doctor of Philosophy, Iowa State University, 1934.

phrase; and still others called for a short explanation, provided this explanation was stated briefly and with similar words in all six textbooks. "A common characteristic of all these Type-A items is that a pupil who has memorized the statements with which they are concerned may succeed in the items, even though his understanding of the statements is on a relatively low level. The common purpose of these items was to find how many pupils had *memorized* certain textbook statements, regardless of the degree of understanding they possessed."

Type B possessed these characteristics: Each item was directly related to a statement with which a Type-A item was concerned; some items asked the pupils to state in their own words what a certain word, phrase, or statement meant; others asked the pupils to recognize the correct meaning of a word, a term, or a statement when the meaning was expressed in a new or unfamiliar phrasing. Certain ones required the pupils to provide or to recognize in an unfamiliar form, the correct meaning of a word or phrase as it was used in a textbook statement; certain others asked the pupils to state or to recognize a correct explanation or interpretation (presented in unfamiliar form) of a given phenomenon; and still others required the pupils to state or to recognize a fact, and then to state or to recognize a reason why the fact is true. "A common characteristic of these items is that they cannot be answered simply by supplying or recalling a stereotyped textbook statement. To succeed in these items the pupil must recognize the idea of the original statement when presented in a different and often unfamiliar form, use the idea in explaining or interpreting a phenomenon, or describe the meaning of the crucial words in the original statement. The common purpose of these items is to determine the extent to which the pupils understand the statements on which the Type-A items are based."

Of the seven tests used, respectively three and four tested knowledge and understanding of *heat* and of *electricity*. The tests were administered as soon as the work on each unit had

been completed. The tests were administered to approximately three hundred pupils in 34 Iowa schools selected at random. Scoring was done so that tabulations could be made on a Hollerith machine. Reliability coefficients were computed on half of each test by the chance-halves method; and then for the whole test by using Brown's Formula. All the coefficients of reliability of the seven tests ranged from $.862 \pm .009$ to $.925 \pm .005$.

In analyzing the data ". . . the pupils who wrote each test were divided into 10 'ability' groups according to their total scores on the test."

Findings.—1. "The average number of correct answers to the Type-A items was from 50 per cent to 60 per cent higher than the average number of correct responses to the Type-B items."

2. "The extent of rote learning was much more pronounced in the low-ability groups than in the high-ability groups, but there was a significant amount of rote learning at all levels of achievement."

3. "The pupils who gave the correct responses in the Type-A items were more able to succeed in the Type-B items than the pupils who were not able to recall the statements on which the Type-A items were based."

Conclusions.—1. "Stereotyped textbook statements in the subject matter of high-school physics are memorized, on the average, by about 70 per cent of the pupils, but only 17 per cent of all the pupils develop a 'satisfactory' understanding of these statements. Of the pupils who memorize the statements, approximately 25 per cent develop a satisfactory understanding of them. Approximately 50 per cent of the pupils who are able to recall a textbook statement are able to show an understanding of the statement by succeeding in a single test item that presents the statement in an unfamiliar form, or that requires use of the statement to explain a phenomenon. These findings are particularly significant in view of the fact that the

items used to determine whether or not the pupils had a 'satisfactory' understanding were quite simple and closely related to the explanations given in the textbooks."

2. "If achievement in high-school physics is measured with tests that require only the recall of textbook statements in their familiar phrasings, the test results greatly exaggerate the achievement which the pupils have actually attained, because many pupils succeed in these tests by repeating or recognizing statements which they do not understand. Likewise, if the class recitation is concerned chiefly with the repetition of textbook statements, the teacher cannot tell whether or not the pupils have developed or are developing the understanding which they need to develop, if the statements are to serve them in the situations and for the purposes described by the objectives of instruction."

STUDY NO. 191

A Study of Certain Mathematical Abilities in High-school Physics[1]

By William Ray Carter*

Problem.—To determine the extent to which we may "expect high-school physics students to be able to recognize the mathematical concepts involved in reading and understanding the text and other expositive material in high-school physics."

Method.—An analysis was made of the three textbooks of high-school physics which were most frequently used in the

[1] Compare this study with that by Kilzer, *Investigations in the Teaching of Science*, Vol. II, pp. 215–216.

* Dissertation for the degree of Doctor of Philosophy, University of Missouri, 1932. This study was published, complete, in *The Mathematics Teacher*, XXV (October, November, and December, 1932), 313–331, 388–419, and 451–469. Copies can be obtained from the investigator at the School of Education, University of Missouri.

Missouri high schools in 1927–28, in order to determine "the approximate frequency of occurrence in the physics context of each of the mathematical concepts in Schorling's[1] list . . ." Concepts to serve as the basis of a test were selected from this list in accordance with these criteria:

A given concept, in order to be included in the test, must be common to all three texts analyzed

That concept is most acceptable for test purposes which occurs in the greatest number of chapters or sections of the texts analyzed

The concept must not be too obvious in the context in which it occurs

By the use of these criteria 30 concepts were selected from Schorling's list, and to these were added three others "which occurred many times in the texts analyzed." ". . . representative statements of facts, laws, or principles from physics which include these concepts in context" were selected in accordance with the following criteria:

A statement or test item that involves a given concept must not contain the word that names the concept

A statement selected as a test item must contain a given concept in a valid mathematical form, and must not contain words that are used in a different sense in mathematics

The statement used to illustrate a given concept must be a straightforward statement of fact and not purely hypothetical

As far as possible, statements clearly involving more than one mathematical concept should be avoided

No statement involving too complex a sentence structure or unusual vocabulary difficulties should be used, for the test might then become a test of reading ability

Two forms of multiple-response test consisting each of 33 laws, principles, or facts selected from the three physics texts which were analyzed, and involving the 33 mathematical concepts previously selected, were constructed and in April,

[1] Raleigh Schorling, *A Tentative List of Objectives in the Teaching of Junior High School Mathematics, with Investigations for Determining Their Validity* (Ann Arbor, Michigan: George Wahr, 1925).

1930, were administered to 162 physics students in six Missouri high schools. On the basis of their responses the test was revised into its final form.[1] "The application of the self-correlation technique and the Spearman-Brown Formula to the results of this test in its final form as administered to 526 students gave a reliability coefficient of .88 ± .007."

This test, The Carter Test for Mathematical Concepts in High-school Physics, was made one of a battery of five tests which included the Otis Self-administering Tests of Mental Ability, Higher Examination, Form B; The Nelson-Denny Reading Test for Colleges and Senior High Schools; The Butler Test for Mathematical Concepts; and the Kilzer-Kirby Inventory Test for the Mathematics Needed in High-school Physics. This battery was administered to 477 pupils enrolled in classes of physics in 13 high schools of Missouri. Complete returns used in this investigation were obtained from 274 boys and 130 girls. The median age of these 404 pupils was 17 years, two months; the mean number of semesters of training they had had in high-school mathematics in Grades IX to XII, 4.8; and the mean number of semesters of training they had had in high-school science, other than physics, in Grades IX to XII, 2.3.

The battery of tests was administered in from three to five class periods at intervals of from one to two weeks in each school. "In most cases the interval between the first test and the last in any given school was about five weeks and in no case was it more than nine weeks."

The data from the administration of each test were given an elaborate statistical treatment which included computations of the median, Q_1, Q_3, the range, the mean, the S.D., and the coefficient of variation, for each distribution; also various statistical comparisons were made of data secured on the different tests; and of the data obtained from this group with that

[1] W. R. Carter, *The Carter Test for Mathematical Concepts in High-school Physics* (Columbia, Missouri: The University of Missouri, 1930).

secured by other investigators with comparable groups in other schools.

Conclusions.[1]—1. "The ability to recognize mathematical concepts occurring in the reading of high-school physics seems to be an important factor in the comprehension of physics materials."

2. "The ability to recognize mathematical concepts in high-school physics . . . seems to be primarily a mathematical ability . . ."

3. "There is a higher correlation between reading ability and the ability to recognize mathematical concepts in high-school physics than between reading ability and computational ability, as these abilities are measured by the tests employed in this study."

4. "The ability to recognize the mathematical concepts in high-school physics bears an important relation to performance in physics."

5. ". . . high-school physics students, on the average, show a relatively high degree of performance with respect to the ability to recognize the mathematical concepts in high-school physics . . ."

6. "The results from the tests employed in this study indicate that, with the exceptions of computational ability and a variability of performance on some tests, the differences between boys and girls are not great enough to be considered very significant."

7. "The wide range in reading ability shown to exist between physics students . . . may be of considerable importance with respect to the time which must be spent by different pupils in mastering a given assignment."

8. ". . . high-school physics students have a relatively high degree of ability to recognize in physics materials the mathematical concepts . . . [but] physics teaching as now conducted

[1] Only those conclusions from an extensive list which refer specifically to pupil-learning of high-school physics are included here.

. . . apparently does not contribute to any appreciable extent to the pupils' ability to react to the quantitative aspects of the subject . . ."

9. ". . . there seems to be some justification for the mathematical prerequisites which are now required by some schools for admission to the physics course," but "the performance of many members of the group on certain fairly simple items in the mathematics tests which purport to measure mathematical abilities in physics situations, indicates that the fundamentals of mathematics are not thoroughly enough mastered by a large percentage of high-school students to enable them to apply these fundamental processes in a field such as physics."

10. ". . . there is some justification for the inclusion in the physics course of the exercises of a computational nature which are now found in most physics textbooks."

STUDY NO. 192

An Investigation of Accomplishment in High-school Physics by Means of Diagnostic Tests

By Lynn Louis Ralya*

Problems.—(1) "To discover through the use of intensive objective tests, designed especially for the purpose, the degree of accomplishment with regard to those specific concepts, facts, principles, laws, and generalizations which are assumed by present-day high-school physics curricula to constitute the specific objectives in the field of *mechanics;*[1] (2) to discover,

* Unpublished dissertation for the degree of Doctor of Philosophy, University of Wisconsin, 1933. An abstract of this study under the title given here appears in *Phi Bulletin* (Phi Delta Kappa, University of Wisconsin, Madison, Wisconsin), XII (June, 1935), 2–6.

[1] This study was subsequently extended to include also the fields of *heat*, *electricity*, *sound*, and *light*, and the results, in mimeographed-bulletin form, were distributed through the Bureau of Educational Research of the

through the use of the same tests . . . the general level of accomplishment in the topics represented by the separate subtests, unit tests, and summary tests; and (3) to suggest in the light of the findings of the investigation means by which the level of student accomplishment may be raised."

Method.—An analysis was made of the five most popular textbooks of high-school physics (three published in 1937, and two in 1929), to determine the topics and the "specific concepts, principles, laws, generalizations, and abilities to be covered within each topic," and to locate sources of possible misunderstandings, misconceptions, and difficulties such as had been indicated by the results of previous diagnostic testing by the investigator in his own classes. Using the results of this analysis, the investigator constructed a battery of 18 unit tests totaling 585 items, which in his judgment covered all the desired points found in the unit on *mechanics*, and which followed the general order of the corresponding points in the texts. These test items were of the short-answer, completion, true-false, multiple-response of two or more choices, and computative types. Many were provided with diagrams. A summary test of 150 items (thirty 5-item multiple-response groups, having an indefinite number of correct responses) was also constructed to measure the degree to which major concepts, principles, laws, and applications had been grasped by the students. A second form of summary test composed of 150 true-false items covering the same materials as the first summary test was also prepared.

The co-operation was secured of teachers of physics in 24 schools in towns chiefly of Wisconsin, varying in population from two thousand to thirty thousand. The number of pupils studying physics in these schools varied from 10 to 75. The unit tests and the summary tests were administered in these

University of Wisconsin, to teachers of physics in a large number of Wisconsin high schools.

schools. In order, moreover, to "see that a reasonable number of schools and a reasonable number of pupils took each test," the co-operation of additional schools was secured "as occasion demanded." The numbers of schools giving the various subtests ranged from six to 11; the summary multiple-response test was administered in 11 schools and the summary true-false test in seven.

The tests were administered by the regular classroom teachers, immediately upon the completion of the work covered by the particular test. The papers were scored by either the teacher or the pupils, who used a key provided by the investigator. The scoring of some of the unit tests was checked by either the pupils or by their teacher, and that of most of the summary tests, by the teachers. After the papers had been scored and their scoring had been checked, the papers were in many cases discussed in class. The scorings of tests returned to the investigator were re-checked by him *in toto* or by a process of sampling. Tabulations were made of the correct and incorrect responses for each pupil, of the total score of each pupil, and of the percentages of pupils who responded correctly and incorrectly to each item. These percentages were considered indexes of accomplishment in the specific abilities measured. Computations were made of the means, medians, and S.D.'s of the scores. Also the reliabilities of the tests were computed by the chance-halves method.

Findings and Conclusions.—1. "Achievement was restricted but little," except in a few places, "by failure to know important English units and important metric equivalents."

2. Achievement was considerably restricted by lack of knowledge of methods of converting values from English to metric units and *vice versa*.

3. A considerable number of students did not possess clear concepts of volume and of mass and weight.

4. "Accomplishment was severely restricted by failure to compute correctly the circumference of a circle with a radius and the value of *pi* given . . ."

5. "Low accomplishment was the rule on problems involving the extraction of square root."

6. Direct and inverse variation were not well understood and direct and inverse variation as the square or square root were even less well understood.

7. "Knowledge of the factual was sometimes considerably greater than understanding of the principle behind the factual."

8. "Success in recognizing a verbal statement as true did not always involve understanding it and the ability to apply it."

9. "Success in reproducing or recalling a formula was sometimes much greater than the success in solving problems . . . by its use" and "was sometimes greater than the understanding of the relationships represented by the formula."

10. "Success in solving problems was sometimes greater than the understanding of the physical principle upon which the intelligent solution depended."

11. Important principles were sometimes not carried from topic to topic in the student's thinking as they might have been and probably should have been to secure continuity and coherence in the understanding of the subject. Notable illustrations of this weakness were in the failure to apply the laws of motion and gravitational attraction to the explanation of why a freely falling body falls as it does, and the failure to apply the principle of work to all types of simple machines.

12. "Accomplishment was sometimes considerably greater on questions which did not involve exactly quantitative knowledge than on these questions concerning the same principle which did. For example, more knew that gravitational attraction becomes less as the distance increases than knew it decreases exactly with the square of the distance."

STUDY NO. 193

Some Effects of Irrelevant Data in Physics-test Problems

By Robert L. Ebel*

Problem.—To determine "the actual effect of irrelevant data on the difficulty and discrimination of individual-physics-test problems, and the changes which the inclusion of irrelevant data brings about in the measuring characteristics of the test as a whole."

Method.—A group of 30 problems relating to the principles of *mechanics* and *heat* was selected from the Iowa Every-pupil Test in Physics for the years 1932, 1933, 1934, and 1935. "For each of these problems an alternative statement containing one item of irrelevant data was formulated." This item was so selected that it bore "a definite relation to some element of the problem in which it occurred, which could be used with the other information given to arrive at a plausible, incorrect answer, but which could not be used to give the correct answer." The italicized portions of the following problems illustrate such irrelevant data:

What is the actual mechanical advantage of a block and tackle, if a force of *2 lbs.* moves 10 ft. while lifting a weight to a height of 2 ft.?

What is the H.P. of an engine which, *attached to a wheel and axle having a mechanical advantage of 2*, can lift 1,100 lbs. to a height of 2 ft. in 1 sec.?

A spring *weighing 5 gm.* has a length of 6 in. when it supports 10 gm., and a length of 8 in. when it supports 15 gm. How long would it be if it supported 30 gm.?

"The problems were divided into two tests, each of which contained both standard and irrelevant-data problems. A third test, designed to measure general achievement, was built by selecting 81 of the most discriminating verbal items from the same Every-pupil tests."

* *School Science and Mathematics*, XXXVII (March, 1937), 327–330.

"The three tests were administered to high-school physics students in five Iowa high schools. The teachers were directed to administer the second problem test several days after the first, and to give the achievement test during the intervening days. This order of presentation helped to limit the carry-over of remembered responses from a problem to its homologue."

"One hundred fifty complete sets of papers were returned. . . . The percentage of pupils who failed to answer a given problem correctly was called the index of difficulty for the problem." For a measure of the value of a problem as a means of discriminating between pupils of high and pupils of low achievement, "the biserial coefficient of correlation for each problem was figured both on the basis of the pupils' total scores on the achievement test, and on the basis of their total scores on the problems. This measure is known as the index of discrimination."

Findings and Conclusions.—1. "A striking variation, from problem to problem, appeared in the effects of the irrelevant data. The difficulty of some problems was greatly increased by the inclusion of irrelevant data. In other problems, an apparent decrease in difficulty accompanied the introduction of irrelevant data. Similar statements can be made with reference to the discriminatory ability of the problems."

2. "The correlation between achievement test scores and scores on the standard problems was .719 $\pm$ .026, between achievement test scores and scores on the irrelevant data problems was .714 $\pm$ .027, and between scores on the standard problems and scores on the irrelevant data problems was .921 $\pm$ .008. Evidently the inclusion of irrelevant data in the physics problems did not change, and hence could not improve, the characteristics of the test as a measure of functional achievement. This lack of a significant difference between scores on the two types of problems would be expected on the

basis of a wide variation in the effects of irrelevant data on the individual problems."

3. ". . . the inclusion of irrelevant data in physics problems cannot be justified on the basis of improving the discriminatory ability of the items in general, or on the basis of improving the measuring characteristics of the problem test, unless the 'effective' item or items of irrelevant data for each problem have been selected through trial on a large group of students."

STUDY NO. 194

Instructional Values of Work-sheets[1]

By Archer Willis Hurd*

UNIT I

Problem.—To determine whether the use of work-sheets increases pupil achievement in high-school physics.

Method.—"During the school years of 1927–28 and 1928–29, 19 teaching units were prepared, and many of these were used experimentally in several schools.[2] During the school year 1929–30 a workbook was prepared recasting the units for use by the pupils." These revised units were used in 16 experiments, involving 280 pairs selected from 1,125 pupils enrolled in classes of physics in 12 high schools. Pupils in the experimental (X-) and the control (C-) classes were matched on several different bases, in most cases chronological age, grade in school, sex, and score in the pretest.

[1] Compare this study with that of Corbally, *Investigations in the Teaching of Science*, Vol. II, pp. 105–108.

* The first unit is reported under the title, "The Workbook as an Instructional Aid," in *The School Review*, XXXIX (October, 1931), 608–616; the second appears as, "The Textbook *versus* Worksheets in Instruction," in *Educational Administration and Supervision*, XVII (December, 1931), 661–664.

[2] A. W. Hurd, "Reorganization in Physics," *North Central Association Quarterly*, IV (September, 1929), 277–293.

In the first two of these paired-group experiments, an attempt was made to contrast a lecture method with a supervised-study method in which work-sheets were used. In the remaining experiments work-sheets were used in the X-groups but not in the C-groups. All other procedures in teaching and the time allotments as well, were the same in both X- and C-classes.

The same tests "designed to parallel the work-sheets in a general way," were administered both at the beginning and the end of each experiment. The mean gains together with the S.D.'s of these mean gains were computed for both X- and C-classes and also for the equated groups composed of the paired pupils from all the classes. The significance of the gains was determined from a computation of the critical ratios (the differences in mean gains divided by the S.E.'s of the differences in mean gains).

Findings.—1. "For the first experiment the lecture method was consistently superior to the supervised-study and work-sheet method in one school; in the other school the results were exactly opposite. In neither case were the differences statistically significant to the degree of certainty."

2. "Eight experiments showed consistent differences favoring the groups using work-sheets, three being significant to the degree of certainty."

3. "Four experiments showed consistent differences favoring the groups not using work-sheets, two being significant to the degree of certainty."

4. "Two experiments showed little difference between groups using and not using work-sheets."

Conclusion.—". . . work-sheets will not overcome the defects of poor instruction but they may be helpful especially in directing teacher and pupil attention to the more important phases of the unit topic by calling for definite, individual reactions to these phases."

UNIT II

Problem.—To determine the relative merits of a "textbook-recitation plan of instruction in high-school physics" and "a special work-sheet plan, using specially prepared objective tests to estimate pupil achievement for both plans."

Method.—This investigation was carried out in 14 high schools during the school year of 1930–31. In every school, "one or more classes used the conventional textbook-recitation plan, lessons being assigned from the textbook and recitations being conducted on the assigned lessons. Similarly, one or more classes used the work-sheet plan, lessons being assigned from a teachers' outline, with work-sheet exercises, and discussions of work-sheet material. A preliminary test was followed by 14 days of instruction after which Final Test Form A was given, followed the next day by Final Test Form B." The reliability indexes of these tests were respectively .96 and .92 with small S.E.'s. "The same instructor taught all classes in the same school, and cautions were suggested to prevent carry-over from one plan to the other."

Critical ratios of the differences in mean scores and in mean gains were computed as in Unit I, not only for the paired groups but also for the unequated classes in which the paired pupils were taught. "Individuals in the equated groups were also compared by finding the number and percentage of those in one group exceeding their paired companions in the other group, and by finding the number and percentage of those in one group exceeding the mean of the other group."

Findings.—1. Of the 36 comparisons "made between means for equated groups in individual schools for Final Test Forms A and B and gains, 22 favored the work-sheet plan, and 14, the textbook-recitation plan." Since a critical ratio of 3.00 or more is considered as indicating a significant difference between the two factors compared, four of these gains were significant

for the work-sheet plan, and five for the textbook-recitation plan.

2. "When the percentage of the work-sheet groups exceeding the mean of the corresponding textbook groups was used as a criterion of difference, in the two plans for 36 similar comparisons, the percentage was 50 per cent or higher in 21 cases; 60 per cent or higher in 14 cases; and 75 per cent or higher in eight cases."

Conclusion.—"It is evident that it cannot be said that in all cases a work-sheet plan is superior to a textbook-recitation plan. It can be said, however, that work-sheets are of use to many teachers in helping pupils to make more satisfactory achievement on a planned teaching unit such as that used. . . . Work-sheets may be a positive detriment to some teachers in their teaching . . . It is probably safe to consider work-sheets as aids which may be of service if they are used wisely, but which must be used with discretion in order to be of aid."

STUDY NO. 195

A Work-sheet for High-school Physics

By Charles A. Browning*

Problem.—To determine the relative value of two methods of teaching physics, one employing conventional procedures, the other based upon the use of a workbook.

Method.—This investigation was conducted with two classes of physics in the Knoxville, Tennessee, High School. These classes numbering 30 each, were "comparable as to I.Q., age, sex, previous science training, mathematical ability, and reading ability." One class, the experimental (X-) group, was taught by the use of the Hurd Work-sheets.[1] The other class,

* *Science Education*, XVIII (February, 1934), 37–41.

[1] A. W. Hurd, *A Workbook in Physics* (New York: The Macmillan Company, 1931).

the control (C-) group, was taught by the "ordinary assignment, recitation-the-next-day method, accompanied by lecture-demonstrations and student laboratory experiments."

"In the X-class, one assignment was made at the beginning of each unit. There was no reciting, but instead, the pupils spent the entire [60-minute] period, with the exception of a 6-minute summary, in reading the various texts and in solving the exercises in the workbook which were focused on the understandings of the units. While the pupils were working, the instructor moved around in the room answering individual questions and giving individual instruction. Each pupil worked independently. There was no talking in the class except in undertones between the instructor and the individual pupils . . ."

"In the C-class, the 60-minute class period was divided into two parts, 40 minutes for assignment, recitation, and summary, and 20 minutes for study." The assignment, made day by day in the text at the beginning of each period, was prepared out of class and was recited upon the next day. During the study period "the pupils had access to the various texts which were in the room," but "no attempt was made on the part of the instructor to teach, or to assist pupils in their work." During the recitation period the teacher asked questions, used the blackboard in explaining principles, repeated explanations as needed, had pupils solve problems both on the blackboard and orally, and at the end of the period, summarized each day's work and attempted to clear up any points which remained vague in the minds of some of the pupils.

The Hurd tests, which accompanied the work-sheets, were administered to both groups at the beginning and at the end of each of the six units which were covered in the experiment and which "ordinarily constitute the core of the first semester given in high-school physics."

The significance of the results was determined by computing the standard errors.

Conclusions.—1. Though the results of the tests were not uniformly in favor of either method, "it seems safe to conclude from data obtained in this study that, in so far as the tests were valid and the two classes comparable, the work-sheet method of teaching high-school physics, as described in this investigation, is slightly superior to the recitation method, when all pupils and all units studied are considered."

2. "When judged on the basis of information retained through the semester . . . the class taught by the recitation method retained knowledge slightly better than those of the class taught by the work-sheet method," though the difference was not statistically a significant one.

3. ". . . superior pupils may be expected to profit more by the use of physics work-sheets . . . than inferior pupils."

4. ". . . pupils of less than normal mental age would profit most when taught by the recitation method."

STUDY NO. 196

What Factors Make for Good or Poor Achievement in Science

By Archer Willis Hurd*

Problem.—To determine (1) the extent to which satisfactory achievement in school courses is dependent on the diligence with which pupils apply themselves; (2) why some pupils do not apply themselves; (3) what effect interest has on achievement; (4) what effect a pupil's extracurricular activities have on his school achievement; (5) what effect his natural mental capacity has on his achievement; and (6) what effects desirable character traits have on achievement.

Method.—This investigation involved high-school pupils who were studying physics in more than twenty high schools.

* *Science Education*, XX (February, 1936), 4–7.

For each criterion, a pupil was matched with another pupil from the same class in the same school. Two equivalent forms of a test, each form composed of 119 items, based on the instructional unit, *Sound, Music, and Hearing* were administered, one as a preliminary and the other as a final test. "In making group comparisons the difference between mean percentages of possible score gains for the compared groups were divided by the standard errors of these differences in order to get critical ratios." "Conventional achievement in this experimentation was represented by the per cent of possible gain made by pupils from preliminary to final test. . . . To get the per cent of possible gain, the difference was found between final and preliminary scores for each individual and divided by the difference between his total possible score and his preliminary score. This was expressed in per cent."

These test scores were supplemented with data secured from a questionnaire and other specifically recorded data. Additional studies were made of the 28 highest and the 28 lowest pupils enrolled for the experiment in all schools; and also case studies were made of the highest and the lowest pupils.

Findings.—1. ". . . on the average, pupils having a great liking for physics make higher achievement ratings . . . than do those who do not possess this liking for the subject. This same conclusion is borne out with expressed liking for general science, and to a somewhat less marked degree for chemistry."

2. ". . . there is no such difference in achievement for any comparison between those liking, in various degrees, reading about machinery, reading about electricity, or reading about inventions. The absence of differences in these types of interests is evidence of the validity of the differences obtained in the former comparisons."

3. "Liking for study seems to be attended by higher achievement scores."

4. "Those reporting fewer hours of recreation per day seem to make higher achievement scores."

5. "Achievement scores are higher for those belonging to four clubs when compared with those belonging to no clubs."

6. "Achievement scores are higher for those groups having higher I.Q.'s. Above 130 there is a sharp drop in achievement but it is still higher for those groups than for those below an I.Q. of 120."

7. "Those reporting no help in class work apparently have higher achievement scores than those receiving help."

8. "Data favor those who say that they think health affects their work."

9. "Data favor those who sleep nine or ten hours a night over those who report seven or fewer hours."

10. "Data favor those who come from families of six or more compared with those who report three or less (one child)."

11. "Data favor those receiving high ratings in certain traits including originality, industry, systematization, and conscientiousness."

12. "Data favor boys over girls."

13. "Data favor twelfth-grade over eleventh-grade pupils."

14. "Twenty-three other comparisons made, show smaller differences between groups compared."

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[1] In accordance with the criterion repeatedly stated and indicated by members of the N.A.R.S.T. in connection with their evaluations of the studies presented in this book, no title is included in this bibliography as a report of a research investigation unless it presents a statistical treatment of data obtained in an attempt to solve, by investigational techniques, a clearly stated or indicated problem.

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STUDY NO. 197

An Analysis, Evaluation, and Synthesis of Subject-matter Concepts and Generalizations in Chemistry

By Clarence Martin Pruitt*

UNIT I

Problem.—To determine the concepts and generalizations in the field of chemistry which are of most distinctive value to man in interpreting his environment.

Method.—An analysis was made of 65, 92, and 166 questions, respectively, of the New South Wales, the New York State Regents, and the College Entrance Board examinations, and of "slightly more than fifty thousand pages of material" included in five books of sociology; one year's issue of each of three magazines, *The Atlantic Monthly*, *The Forum*, and *Harpers Magazine;* one year's issues of eight newspapers; 12 issues each of *Popular Science Monthly*, *Scientific American*, and *Science News Letter*, and nine issues of *Scientific Monthly;* four books of astronomy; seven books of biology; two books treating miscellaneous scientific topics; five books of geology; five books of physics; three textbooks of science (not chemistry) for high schools; six textbooks of science (not chemistry) for colleges; nine years issues of the *Journal of Chemical Education;* two textbooks of chemistry for high schools; and 22 popular books of chemistry. From this analysis were obtained chemical concepts and generalizations, which were listed along with their frequencies of appearance in all the sources.

Findings.—1. "Little material relating to the composition, behavior, and properties of matter is found in books on sociology." Considerable attention is paid to the social

* Dissertation for the degree of Doctor of Philosophy, Teachers College, Columbia University. Published by the author: New York, 1935. Distributed through *Science Education*.

implications of science and how science has shaped, is shaping, and will continue to shape thought and action in social, economic, and industrial life.

2. "Magazines of the type such as the *Atlantic Monthly*, *Harpers*, and *Forum* contain very little material common to the field of chemistry."

3. "The average American newspaper contains relatively little chemistry. The *New York Times* is an exception to this generalized statement. In the newspapers examined, concepts and generalizations relating to the structure of matter and physiological properties receive major emphasis."

4. "Scientific magazines of a general nature contain a considerable amount of material relating to the structure, behavior, and properties of matter. The emphasis is strikingly similar to that of newspapers. Very little attention is paid to gas laws or the quantitative aspects of chemistry."

5. "Popular books in astronomy contain considerable chemistry with major emphasis on the structure of matter and the identification of elements by spectrum analysis."

6. "Physiological and organic chemistry receive an emphasis almost to the total exclusion of other phases of chemistry in popular books in biology. Little attention is paid to the structure of matter."

7. "Relatively less attention is paid to chemistry in popular books in geology than in the popular books in the other sciences. States of matter, solution, and density receive major emphasis."

8. "States of matter and structure of matter receive major emphasis in popular books in physics. . . . more chemistry is found in popular books in physics than in those of any other field. However, specific concepts and generalizations seem to be somewhat more concentrated in one particular book rather than having a wide distribution."

9. "Collectively, popular books in science (other than chemistry) emphasize such phases of chemistry as states of

matter, structure of matter, physiological properties, and organic chemistry. Such familiar phases as gas laws, theory of ionization, types of chemical reactions, and the quantitative aspects of chemistry receive only slight reference."

10. "Equation and formula writing and problem solving seem to be receiving major emphasis in New York State Regents Examinations. The theory of ionization and structure of matter rank fairly high, but organic chemistry is almost completely ignored."

11. "College Entrance Examinations Board Questions give major emphasis to problem solving, writing equations and formulae, specific tests for substances and the theory of ionization. Only slight changes have been made in the type of questions asked during the last two decades."

12. "In the high-school science textbook field, most chemical concepts and generalizations are found in physics textbooks and least in biology textbooks. States of matter, solutions, elements, compounds, atoms, and molecules rank highest among the concepts. Organic chemistry and physiological chemistry are emphasized in biology."

13. "The emphasis in college science textbooks (other than chemistry) is strikingly similar to that in high-school textbooks, both collectively and individually in the same field."

14. The analysis of the 22 "popular books in chemistry gave the highest total frequencies to the following six concepts: atom, physiological properties, element, metal, compound, and molecule. One or another of the first four concepts ranked first in 15 of the books, while the latter two concepts ranked second in over half of the books examined. Physiological chemistry, organic chemistry, metals, and alloys receive significant attention. Relatively less attention is given to the structure of matter than is given in newspapers and scientific magazines. Little attention is paid to gas laws, the theory of ionization. and the quantitative aspects of chemistry."

15. "Phases of chemistry emphasized in the *Journal of Chemical Education* are quite similar to those in the other science magazines examined, but with a somewhat greater emphasis on oxidation and reduction, the theory of ionization, and organic chemistry."

16. "Examination of chemistry textbooks in the college and high-school fields indicates that significant differences exist between the content emphasized in textbooks and that emphasized in popular books in chemistry and the other sciences, in science magazines, and in newspapers. . . . Much duplication exists between the content of the high-school and college chemistry textbooks examined."

UNIT II

Problems.—"To synthesize and evaluate the concepts in terms of generalizations for use by various workers in the field of science education."

Method.—The concepts and generalizations secured by the analyses of the preceding unit were selected for the final list of generalizations on the basis of the following criteria:[1]

A generalization shall be as simple, comprehensive, and definitely stated as possible

A generalization must be a statement of some fundamental process, or constant mode of behavior or property relating to natural phenomena

A generalization must be true without exceptions within the limitations made in the statement

A generalization must be a statement capable of demonstration

A generalization must not be subordinate to a larger generalization

A generalization must not deal with specific or limited groups of substances

A generalization must not be a definition.

Findings.—The following are the generalizations which were determined by application of the criteria just stated:

[1] Compare with Downing's definition of a principle, *Investigations in the Teaching of Science*, Vol. II, p. 74 (footnote), and with Robertson's criteria of a principle, p. 3, of this volume.

Matter is composed of the atoms and molecules of elements and compounds, ions, electrons, and protons.

Substances have specific physical and chemical properties by which they may be identified.

Every pure sample of any compound or element under similar conditions exhibits the same physical properties and chemical behavior.

Chemical reactions may be initiated or affected, or both, by: heat, light, pressure, catalysts, concentration, the electric current, surface exposed, bacteria, hydrogen-ion concentration, and mechanical disturbances.

Elements and compounds produce physiological effects to which the cells of living organisms react specifically.

All matter may change its physical state by absorbing or releasing energy.

The relative velocity of molecules and their tendency to cohere determine the physical state of a substance.

Metals comprise a group of elements (other than hydrogen) whose atoms have a tendency to lose electrons readily and whose compounds when dissolved in polar solvents are capable of forming positive ions.

Atoms of the same element have similar properties but have different properties from the atoms of other elements.

Molecules of the same element or same compound are alike but are different from the molecules of other elements and compounds.

A given compound, whatever its origin, always contains the same elements in the same proportion by weight.

Enzymes, vitamins, and hormones are chemical regulators of the reactions that occur in living organisms.

The properties of alloys are dependent upon the relative amounts of their constituents and upon the crystalline structure of the particles.

Acids and bases are substances which in water solution ionize to give hydrogen or hydroxyl ions, respectively, from their constituent elements.

The solubility of solutes is affected by heat, pressure, and the nature of the solute and the solvent.

The ingredients of a solution are homogeneously distributed through each other.

The exchange of the negative and positive ions of acids and bases results in the formation of water and a salt.

When elements combine with each other, a substance is formed having properties almost entirely different from those their constituents had as elementary substances.

In a mixture, there is an intermingling of two or more substances with no fixed percentage composition and each ingredient retains its essential original properties.

The atoms of a given element are unvarying in average mass but are different in average mass from the atoms of all other elements.

Carbon atoms have the unique property of being able to form chain-molecules and ring-molecules.

Oxidation and reduction occur simultaneously and are quantitatively equal.

Oxidation involves the removal of electrons which increases the active valence of a positive element or decreases the active valence of a negative element, whereas reduction is the converse.

Every molecule of a given substance always contains the same number of the same kinds of atoms.

Carbon atoms form a number of "type-groups" of compounds which are determined by the elements present and by the structural combinations of the atoms within the molecule.

Electrolytes (acids, bases, and salts) when dissolved in a polar solvent or heated to a molten state, undergo dissociation into an equal number of oppositely electrically charged particles (called ions) capable of conducting an electric current.

An invariable relationship exists between the weights of the atoms of all of the elements, and between these weights and the weights of all the molecules which these atoms form.

Matter is not created or destroyed in ordinary chemical changes.

Energy may be transformed in ordinary chemical and physical changes, but it cannot be created or destroyed.

Forms of energy are interchangeable.

A quantitative relationship exists between the weights of the substances that take part in a chemical change and between the weights of the substances reacting and the weights of the product.

Each element, with the exception of those that are inert, has a definite combining weight.

The physical and chemical properties of elements are periodic functions of their atomic numbers.

Ordinary chemical reactions involve either a transfer or a sharing of the outer electrons of atoms.

The differences between atoms of different elements are due to the number of electrons and protons in the nucleus and to the varying number of excess electrons in the shells surrounding the nucleus.

Crystalline structure, heat treatment, and impurities affect the properties of metals.

Pressure affects the boiling point, melting point, and freezing point of substances.

Atoms of radioactive elements are spontaneously emitting various rays and disintegrating into atoms of other elements.

Chemical reactions are brought about by combination, decomposition, displacement, exchange, and molecular rearrangement.

Chemical reactions go to completion when one of the products is a gas, or is insoluble or non-ionizable.

Chemical changes always involve an accompanying energy change.

The tendency of atoms to complete their outer shell by adding, losing, or sharing electrons determines their chemical activity.

Atoms become ions and ions become atoms, when either gains or loses electrons.

All gases and most liquids and solids expand with an increase in temperature and contract with a decrease in temperature.

Gram-molecular weights of non-ionizable substances or half gram-molecular weights of ionizable substances elevate the boiling point and depress the freezing points of solvents equally.

Non-metals comprise a group of elements whose atoms tend to gain electrons readily and whose compounds, when dissolved in polar solvents, are capable of forming negative ions.

Molecules containing carbon atoms have the property of combining with atoms of other elements either directly or by substitution.

Compression heats gases, resulting in increased molecular motion and pressure.

Each element in a state of incandescence has its own characteristic spectrum.

Molecules are in continual motion which molecular motion results in heat and pressure.

Every atom contains an equal number of electrons and protons which have a planetary system of arrangement within the atom.

Electrons and protons are arranged in some 92 patterns, most of which seem to be more or less distributed throughout space.

Metals may be arranged in an activity series according to their tendency to pass into ionic form by losing electrons.

Non-metals may be arranged in an activity series according to their tendency to pass into ionic form by gaining electrons.

Elements arranged in order of their increasing atomic numbers form themselves into a table of natural periods and groups in which the elements of any group have a close resemblance to each other in their respective chemical behavior and physical properties.

Heat increases molecular motion.

Each atom has the property of losing, gaining, or sharing a definite number of outer-shell electrons.

Each shell of an atom contains a definite number of electrons.

Mass of the atom is concentrated in the nucleus.

Atoms with complete outer shells are chemically inert.

Electrons revolve in circular or elliptical orbits about the nucleus.

The volume of any gas varies inversely as the pressure, if the temperature remains constant.

The volume of any gas is directly proportional to the absolute temperature, if the pressure remains constant.

When chemical changes occur between gases, there exists a simple whole number ratio between the volumes of the reacting gases and the volumes of the gaseous product.

The activity of an acid or a base is proportional to the degree of ionization of the compound when in solution or in the molten state.

Equal volumes of all gases under similar conditions of temperature and pressure contain the same number of molecules.

A gram-molecular weight of all gases under similar conditions of temperature and pressure always occupies 22.4 liters.

Suspended particles of colloids have a continuous, erratic movement due to colloidal and molecular impacts.

Compounds may have the same number and kind of atoms but have different properties because of different atomic arrangement and space relations.

During electrolysis, the electrolyte is permanently decomposed, the cations moving to the cathode where they gain electrons and become atoms, and the anions moving to the anode where they lose electrons and become atoms.

Positive and negative ions unite to form molecules.

Each specific ion has a specific test by which it may be identified.

A gram-molecular volume of any gas contains approximately 6.062×10^{23} molecules.

Chemical changes between electrolytes in solution take place more readily than do chemical changes between non-electrolytes in solution.

The weight of gas which a given volume of inert solvent will dissolve is directly proportional to the pressure.

When an element combines with another element in more than one proportion, the different weights of that element which combine with a fixed weight of the second element, are always in the ratio of small whole numbers.

The relative rates of diffusion of gases under similar conditions are inversely proportional to the square roots of the densities of the gases.

The amount of heat evolved or absorbed in the formation of a given substance is always the same, regardless of the rate at which the reaction proceeds or the number of steps in which it takes place.

In a given chemical reaction, the speed of the reaction is proportional to the molecular concentration of each of the interacting substances.

All atoms (except those of hydrogen and helium) are built up from helium nuclei.

Heat, bases, acids, and oppositely charged particles cause colloids to precipitate.

In a gas the molecules have free and independent motion, are relatively far apart, and by virtue of their great velocity produce equal pressure in all directions.

In a liquid the motion of the molecules is less rapid than in gases and cohesive forces tend to hold the molecules closer together.

In a solid the motion of the molecules, ions or atoms is such as to cause them to have a somewhat vibratory motion about mean positions, a condition which may permit of crystalline structure.

The pressure exerted by each component in a gaseous mixture is proportional to its concentration in the mixture and the total pressure of the gas is equal to the sum of those of its components.

Colloids do not diffuse through membranes which are permeable to molecular or ionic dispersions.

A stream of moving electrons constitutes a current of electricity.

Two unlike metals in an electrolyte so react as to cause a flow of electrons.

Equilibrium exists in a chemical reaction when the rates of two opposing reactions of a reversible reaction are equal.

In reversible reactions, the products of the reaction react with each other to form the original reacting substances.

Colloidal particles carry electrical charges.

Radioactive changes involve nuclear changes.

Molecules of some compounds undergo polymerization.

During electrolysis, the amount of substances removed by deposition on the electrodes or released as a gas depends on the total quantity of electricity used.

Atoms behave both as particles and as waves.

Atoms with incomplete inner shells give colored ions.

The more electropositive or the more electronegative an element is, the greater the ease with which it loses or gains electrons.

Colloids have the property of adsorption to an unusual degree.

Electrons change orbits emitting or absorbing energy.

Orderly arrangement of atoms and ions in crystals gives crystals regular form.

Molecular motion ceases at absolute zero.

Heavier atoms may be broken down by bombarding the nucleus with alpha particles.

Atoms have great subatomic energy.

Electrons have a magnetic field.

Liquids usually have greater specific heats than solids.

Some elements have more than one atomic weight due to difference in the proton content of the nucleus.

If some stress is brought to bear upon a system in equilibrium, a change occurs so that the equilibrium is displaced in a direction which tends to undo the effect of the stress.

Each element has its own characteristic *x*-ray spectrum.

Elements may be changed into other elements.

Matter and energy are interchangeable.

Heat of formation and heat of decomposition are equivalent.

The boiling points of hydrocarbons increase with an increase in molecular weights.

Surface reactions predominate in colloidal reactions.

When the temperature of reacting substances in equilibrium is raised, the equilibrium point of the reaction is changed so that those products which absorb heat are increased in quantity, or if the temperature of the reacting substances is lowered, the products which evolve heat in their reaction are increased in amounts.

Salts of strong acids and strong bases undergo slight hydrolysis while salts of weak acids and weak bases undergo a more marked hydrolysis.

Molecular structure affects the properties of molecules.

Metals with loosely held electrons are good conductors of electricity and heat.

The nature and relative amount of the solvent, the presence of other ions, temperature, and light affect the degree of ionization.

For the same quantity of current, the weight of metal deposited or of the gas released is equal to the atomic weight divided by the valence.

For each gas, there is a critical temperature and a critical pressure.

Atomic volume is a periodic function of the atomic weight.

In a saturated solution, the product of the molar concentrations of the ions is constant.

Whenever the product of the concentrations of any two ions in a mixture exceeds the value of the ion-product in a saturated solution of the compound formed by their union, this compound will be precipitated.

Whenever the product of the concentrations of any two ions in a mixture is less than the value of the ion-product in a saturated solution of the compound formed by their union, this compound, if present in the solid form, will be dissolved.

Equal amounts of heat raise equal numbers of atoms of all elements in the solid state through equal intervals of temperature.

The specific heats of elements are inversely proportional to the magnitudes of the atomic weights.

If three elements combine together in pairs, then the quantities of two elements that combine with a fixed quantity of the other element bear a simple relation to the quantities of the first two elements that combine with each other.

When a chemical change takes place without the addition of heat from an external source, that substance which has the greatest heat of formation will tend to form.

Substances soluble in two or more immiscible liquids distribute themselves among the liquids in proportion to their solubilities.

Metals tend to lose electrons readily whereas non-metals tend to add electrons.

Alcohols have the properties of weak acids.

Alcohols oxidize to aldehydes, ketones, and acids.

Alcohols react with acids to form esters and ethers.

Saturated hydrocarbons are relatively inactive chemically, but form compounds by substitution.

Unsaturated hydrocarbons are very active chemically and form many compounds by addition and substitution.

STUDY NO. 198

The Relative Importance of Items of Chemical Information for General Education

By Robert P. Wray*

UNIT I

Problem.—"To determine the relative importance of the items of chemical information that are included in a course in general chemistry."

Method.—Separate analyses of four textbooks of high-school chemistry yielded 1,550 items of chemical information. These items were distributed without classification among 15 lists which were submitted for evaluation to various groups composed of high-school students, teachers, engineers, laborers, housekeepers, medical men, secretaries, business men, pharmacists, and nurses, all of whom had studied "a minimum of one year of high-school chemistry." These individuals were asked to "check the . . . items . . . first as to *Frequency of Occurrence*" (that is, "the relative number of times each item occurred to you in your life activities"); and second, as to *Pleasure*, (that is, "the degree of satisfaction or pleasure that it gives you to understand the item when you meet it in your experience"). These measures were to be indicated in one of five

* Dissertation for the degree of Doctor of Education, Pennsylvania State College. State College, Pennsylvania: Pennsylvania State College, 1933. Reprinted from the *Journal of Experimental Education*, I (June, 1933) as *Penn State Studies in Education*, No. 6; copies are available at the School of Education, Pennsylvania State College. A report of this study appears under the title, "Organization of Secondary-school Chemistry According to Utilitarian Principles," in *Science Education* (December, 1935), 141–149; and also in *The Application of Research Findings to Current Educational Practices*, American Educational Research Association, Official Report, 1935, 118–127.

degrees, thus: for *frequency*, "Never," "Occasionally," "Moderate," "Often," and "Very Often"; and for *pleasure*, "None," "Very Little," "Moderate," "Considerable," and "Great."

About a hundred individuals evaluated each of these 15 sets of items in accordance with the instructions.

The reliability of the evaluations was determined by having a group of 22 graduate students in education and another 38 college Seniors check respectively 60 items and 75 items at two different times, two weeks apart for the first group and four weeks apart for the second; and by then computing the Pearson coefficients of correlation between the two sets of scores of each group. The resulting correlations were .98 ± .008 and .96 ± .008.

The "index value" or "index of usefulness" of each item of information was computed by multiplying the median frequency value of the item by its median pleasure value. The reliability of the "index values" was obtained by computing the Pearson coefficient of correlation between halves, of each of the 15 groups who evaluated a list of items. "In order to show the extent to which the 'index values' assigned by the total of a given group may be said to agree with those that would be given by another similar group, the derived coefficients of correlation from the two halves were 'stepped-up' by the Spearman Prophesy Formula." The resulting correlations ranged from .91 to .96.

In order to indicate the relationship that exists between the evaluations given to the items by the various groups, inter-group correlations of the "index values" were computed by the Pearson Product-moment Formula, and these coefficients were corrected for attenuation. The average inter-group correlations on the 15 questionnaires ranged from .64 to .95.

Findings.—A sample of the final composite list of the evaluated items arranged in accordance with the Periodic Classification of the elements is presented in Table LXXXVII.

Conclusion.—"The high positive inter-group correlations indicate that the items of chemical information have a consistent relative utility for all individuals regardless of occupation, sex, and habitat."

TABLE LXXXVII

INDEX VALUES OF ITEMS OF CHEMICAL INFORMATION

Group O

The Inert Gases

ITEM	INDEX VALUE
1. Helium is used in dirigibles, due to its lightness and non-inflammability	9.87
2. Helium is the most difficult of all gases to liquify	4.64

* * * * *

Group I

A. The Alkali Metals

7. Salt is used in preserving meat and fish for future use as food	13.24
8. Salt is consumed in ice-cream making and other refrigeration	12.28

* * * * *

Group IV

A. The Carbon Family

364. A complete diet must supply vitamins	15.44

* * * * *

UNIT II

Problem.—To determine the extent to which the results of the investigation agree with those of certain other investigations of chemical items.

Method.—Comparisons "sufficiently accurate to show general relationships" were made between the results of this study and those of several other studies.[1,2] "Index values" obtained for topics in this study were compared in turn with the means of the "index values" of all the items concerned with the same topics in the other studies. Also coefficients

[1] J. N. Nathanson, "Commercial Processes in High-school Chemistry," *School Science and Mathematics*, XXVI (June, 1926), 628–633.

[2] Kimber M. Persing, "Present Specific Objectives in High-school Chemistry," *Journal of Chemical Education*, VI (November, 1929), 1959–1978.

of correlation were computed for (1) the "mean index values" of topics from Boorstein's analysis of College Entrance Board Examinations,[1] and the "index values" of corresponding topics from this study; (2) between data from Stemple's study[2] and data from this one; and (3) between "difficulty values" and "index values of usefulness" of topics in this study and those obtained from an analysis of chemistry questions in the College Achievement Test, Part I and for almost all the questions in the Columbia Research Bureau Chemistry Test, Forms A and B.

Conclusions.—1. "That the 'index values' determined in this study are valid, is indicated in the comparison with the study by Stemple whereby it is shown that the 'index values' are in rather close agreement with the extent to which the topics of information function in the activities of subjects ($r = .769$)."

2. There is practically no agreement between the "indexes of usefulness" from this study and importance of commercial processes as indicated by textbook emphasis and by teacher judgment (Nathanson's study); between the "indexes of usefulness" from this study and frequency of mention of objectives (Persing's study); between "indexes of usefulness" from this study and stress of topics in examinations (Boorstein's study); and between the "indexes of usefulness" from this study and the scientific topics discussed in magazines.

3. "The best known items are not considered the most useful, although there is a tendency in this direction."

Recommendation.—"The beginning chemistry course can . . . be adapted in a practical way to the needs of all pupils

[1] J. W. Boorstein, "An Analysis of the College Entrance Board Examinations in Elementary Chemistry for 1921–1928," *Science Education*, XV (January, 1931), 91–100.

[2] F. W. Stemple, Science Needs of Pupils in Small High Schools Based on an Activity Analysis. Doctor's Dissertation (unpublished), Cornell University, 1929.

by building the chemistry curriculum around the evaluated items. The information that ranks highest may be taught to all. Advanced assignments on any unit of work may have quantitative and qualitative differentiation in accord with the abilities and future interests of the students."

STUDY NO. 199

Developing a High-school Chemistry Course Adapted to the Differentiated Needs of Boys and Girls

By Margery Stewart Gillson*

Problem.—To determine what knowledge of chemistry is likely to prove most useful in adult life.

Method.—An analysis was made of 10 books on chemistry written by scientists for the layman, and of eight high-school textbooks of chemistry, in order to obtain lists of objectives[1] in chemistry which could be checked as to their relative usefulness. The resulting list of 340 objectives was reduced to 118 by deleting some which occurred in only two or three sources and by combining others. A further reduction was made on the basis of the responses obtained by submitting this list to the members of the science seminar at Teachers College for "criticism, suggestion, and scoring." During the summer of 1930, the final list of 100 objectives was submitted in mimeographed form to a "general group" of about nine hundred fifty people in various sections of the country. The respond-

* Dissertation for the degree of Doctor of Philosophy, Contributions to Education, No. 709. New York: Teachers College, Columbia University, 1937.

[1] ". . . 'objective' . . . means any statement of fact, principle, generalization, habit, skill, or appreciation which suggests definitely what is to be taught, and, in turn, to become part of the mental equipment of the pupil."

ents were asked to give values of 1, 2, 3, 4, 5, respectively to those objectives which they considered of "Greatest Value," "Great Value," "Value," "Little Value," and, "No Value." They were invited also to suggest additional objectives. Data were tabulated from 400 replies submitted by 143 men and 152 women who had studied chemistry and from 32 men and 73 women who had not, but who checked the objectives they thought would be useful.

A second list of 94 objectives, selected from the preceding list with some additions, was submitted to a "special group" of 256 pupils of the author, who had finished high school three or more years earlier. Of these, 95 boys and 87 girls had studied the usual college-entrance course in chemistry, and the remaining 74 girls had entered a household-chemistry class the second semester. These respondents were asked to indicate the items they had used rather frequently, those they had never used, and those they had used occasionally.

The probable errors of percentage frequency[1] and the probable errors of the differences in percentages were computed,[2] in order to determine whether there were "a real difference in the amount of use that men and women find" for each of the objectives of chemistry. Suggestions made by the pupils in response to an invitation to criticize their high-school chemistry courses were summarized.

As a further means of determining "what chemistry topics are of vital interest to adults, especially women," a comparison was made of the numbers of boys and girls who had won state

[1] $\text{P.E.}_f = .6745\sqrt{\frac{f_p(100 - f_p)}{N}}$

Karl Holzinger, *Statistical Methods for Students in Education* (Boston, Massachusetts: Ginn and Company, 1928), p. 243.

[2] $\text{P.E.}_{(A-B)} = \sqrt{(\text{P.E.}_A)^2 + (\text{P.E.}_B)^2}$.

J. Ralph McGaughy, *Fiscal Administration of City School Systems*, Educational Finance Inquiry, V (New York: The Macmillan Company, 1924), p. 9.

prizes offered by the American Chemical Society in six essay contests over a period of four years; and also an analysis was made of almost a hundred questions pertaining to chemistry which had been submitted by women and which had been answered in *Good Housekeeping* from January, 1926, to February, 1931, inclusive.

The objectives were presented in a number of tables: Chemistry objectives considered more useful by the men than by the women of the general group; and also of the special group; the objectives considered more useful by the women than by the men of each group; the most useful of the objectives of household chemistry; and the objectives considered most useful by both men and women of each group.

Further tabulations were made of the chemistry objectives used occasionally or not at all by the men and by the women of the general and also of the special group; of the chemistry objectives contained only in the household list, which were considered of little or of no value; and of the topics of the chemical essay contests. The interests revealed by the questions found in *Good Housekeeping* were compared with the objectives included in various of the tables prepared from the women's questionnaire replies.

"Conclusions Based on Data."—1. More subject matter of chemistry is useful to both sexes than to either sex alone.

2. ". . . a large amount of the chemistry which is taught in high school does not function in the later lives of the pupils." ". . . the two main reasons for the small use of such a large number of the objectives" are that (1) there is not a sufficiently close relationship between the subject matter presented and the various activities of pupil's daily lives; and (2) the amount of factual information the pupils are asked to learn is too large.

3. Chemistry is of interest to both men and women but "more women than men feel the need of chemistry training in their adult lives."

4. ". . . adults are aware of the value of attacking problems in a scientific fashion."

5. The fundamental principles of chemistry received greater stress than factual information both in the responses to the questionnaire and in the letters sent by the members of the special group. "The principles, or generalizations, which are of most use to laymen . . . are: the composition of matter; the nature of chemical action and the chemist's way of representing it; the chemical theory concerning solutions; the properties of the carbon compounds, acids, bases, and salts; the nature of the metals . . ." ". . . the oxidation-reduction principle and the periodic classification of the elements received low values."

6. ". . . some of the reasons why only a small percentage of the high-school population enroll in chemistry classes are the mathematics involved, the long hours of often meaningless laboratory, and the fact that the course has gained the reputation of being 'hard.'"

"Conclusions Based on Deliberation."—1. "The chemical principles and generalizations which are essential to the understanding of the science, and which will occur frequently in the beginning course and also in many situations in later life seem to be the following: chemical changes—meaning of the term and knowledge of the various types, also some ability in expressing these changes as the chemist does; the oxidation-reduction principle; the theories concerning the structure of matter—atomic, molecular, electronic; conservation of matter and energy; the constant composition of substances and their consequent definite properties; the conditions affecting, and the properties of, solutions, including the ionic theory and some study of electrolysis and colloids; the principle of neutralization and the attending knowledge of the properties of acids and bases; the nature of the metals and non-metals; the electrochemical series; the periodic law; elements of radio activity; the classes of organic compounds; the chemistry of the human

body—food needs, food changes in the body, effects of a few drugs; and enough knowledge concerning textiles and dyes to make intelligent consumers."

Chemical principles and generalizations which may be omitted are the laws of Boyle and Charles, the law of multiple proportions, the law of combining volumes of gases, and Avogadro's Hypothesis.

2. ". . . the chief change in the subject matter of the usual high-school chemistry course should occur in the second semester as now organized. The detailed study of metals should be omitted for girls and a rather extensive study of foods and textiles put in its place. Their study of metals should concern the care of those encountered in the home. This would include the action of the metals with the various acids in food or cleansers and with the air." The study of the principles and generalizations (listed in the second preceding paragraph) "should continually be related to the daily lives of boys and girls in order to arouse their interest and help them to see that chemistry does have functional value for them. Let them analyze or study materials brought from home. The mathematical phases of the subject would not be stressed in a course planned to give girls the chemistry that will be of use during all their lives."

3. ". . . boys would like to know more concerning the structure of matter, the theory of solutions, and the mathematics of chemistry than would girls."

4. "For both boys and girls . . . the starting point of the course should be practical, not theoretical." In order to overcome fear of the course and to develop appreciation of it, "some time should be spent early in the course in giving the class an over-view of the achievements of chemistry in industry, agriculture, and medicine."

5. Laboratory work should form an integral part of the course, closely tied to the classroom discussion and study, and should afford a means of acquiring knowledge first-hand rather than of verifying facts and principles already known.

6. "The slavish use of a single textbook" should be abandoned in favor of gathering data from many sources.

7. Teachers of chemistry must be broadly trained in order that they may orient the pupils and provide a functional course.

8. ". . . if our beginning students are to receive material which will be vital to them, the traditional course must be altered . . ."

STUDY NO. 200

Transfer of Training in Chemistry

By Evelyn L. Mudge*

UNIT I

Problem.—To determine whether "a year of chemistry in high school produces any gain in (1) knowledge of chemistry, and (2) ability to apply this knowledge to the solution of everyday problems involving chemistry and to the intelligent understanding of popular scientific writings."

Method.—An experimental (X-) group composed of 52 pupils of the tenth, eleventh and twelfth grades, and a control (C-) group of 41 pupils of the same grades in one of the large high schools of Washington, D. C., were equated by means and S.D.'s on the bases of mental age, and initial scores on both the Iowa Training Test, Form A, and the investigator's functional test, administered in September, 1932. A comparison of the I.Q.'s and the chronological ages shows the X-group to be somewhat more intelligent (though not to a significant extent) and somewhat younger than the C-group.

The X-group were just beginning work in the regular chemistry course; the C-group took no work in chemistry. In June, 1933, both groups took Form B of the Iowa Training Test and repeated the functional test.

* Unpublished dissertation for the degree of Doctor of Education, Johns Hopkins University, 1935.

The investigator's functional test consisted of two parts: Part I was composed of "a series of verbal descriptions of situations in which the average person might find himself." It "was drafted from questions prepared in previous years for high-school students of chemistry. The majority of the items had been suggested . . . by questions asked by students in the classroom and laboratory." These items were of a modified form of multiple-response test, in which the subject is asked to place in the column marked +, the number of each solution which he considers *effective*, and to place in the column marked −, the number of each phrase which he considers *not effective* or *dangerous*.

Part II, designed to determine the ability of pupils to apply chemical knowledge to the intelligent interpretation of popular scientific literature, was prepared from books selected from a chemistry reading list issued by the American Association for the Advancement of Science. It consisted of both true-false items which the subject was instructed to mark as right or wrong, and items each of which consisted of a series of words accompanied by the direction to draw a line through each one which was not consistent with the idea expressed by the first of the series.

The coefficient of reliability of the test, determined by the Pearson Product-moment Method from the scores of 98 high-school pupils on the odd and the even numbered items was .81. When corrected by the Spearman-Brown Formula for the reliability of a lengthened test, the coefficient of correlation was found to be .89.

Findings.—1. "Measured in terms of raw scores, the chemistry group gained over twenty times as much as the C-group gained on the training test, and five times as much as the C-group gained on the functional test."

2. "For both groups there is an increase in the mean and the spread of the scores on the training test, but the increase is greater for the group studying chemistry. For the X-group,

there is an increase in the mean and spread of scores on the functional test. For the C-group, there is an increase in the mean and a negligible decrease in the spread of scores."

UNIT II

Problem.—To determine the significance of the Findings of Unit I, with respect to "the amount of transfer which occurs from knowledge of chemistry to its application."

Method.—The solution of this problem required three sets of computations: (1) correlation coefficients; (2) partial correlations; and (3) standard scores. To secure the first measure, a correlation was made of the gains by the X-group on the functional and training tests. To obtain the second, the partial correlations were taken for the X-group between mental ages and gains on the functional test when gains in training were held constant; and between gains in training and on the functional test when mental ages were held constant. In determining the third, "gains on both tests were reduced to standard scores [mean scores divided by the S.D.'s of the scores] based on the test scores of 80 high-school students who had just completed a course in chemistry."

Conclusions.—1. "The results indicate that a student who makes a great gain on the training test will probably make a fair gain on the functional test. It does not give any indication of how much of what is learned actually transfers to a practical situation."

2. The coefficient of partial correlation of training and functional gains with mental age held constant, "does not differ greatly from the coefficient of relationship between training and functional gains regardless of mental age. With training gains held constant there appears to be little if any relationship between mental age and functional gain."

3. "In terms of standard scores, 71 per cent is the amount of transfer from knowledge of, to ability to apply, chemistry. This measure is perhaps the most reliable of the three sinc

the gains are in comparable form." "All three measures, however, indicate that there is some transfer."

UNIT III

Problem.—To determine "what residue of factual and functional information persists after an interval of from one to four years since taking chemistry . . ."

Method.—Two groups of respectively 29 and 11 Freshmen from Western Maryland College were divided into two comparable groups on the basis of scores on the Thurstone Psychological Examination. The members of the X-group had all had a course in high-school chemistry from one to three years previously; none of the members of the C-group had had such a course. None of the students of either group were enrolled in any college chemistry course.

A year later, these students were tested with Form B of the Iowa Training Test and with the investigator's functional test.

Findings.—"After a period ranging from one to three or four years since taking chemistry, this group, now in college, has a residue on the training test of 3.4 times that of the non-chemistry group now in college."

UNIT IV

Problem.—To determine the "influence of choice of chemistry upon subsequent scores," and "the relation of choice [or avoidance] of chemistry to intelligence . . ."

Method.—"Four groups of students from Johns Hopkins University and Western Maryland College were selected on the basis of answers to questionnaires . . . designed to discover which students elected or avoided chemistry and which students had no opportunity to elect it." These groups, designated respectively as the "chemistry-choice group," the "chemistry-no-choice group," the "no-chemistry-choice group," and the "no-chemistry-no-choice group," took

the functional test and Form A of the training test. The Thurstone test, together with the functional test and the training test, was also administered to 45 members of the "chemistry-choice group" and to nine members of the "chemistry-no-choice" group.

Conclusions.—1. ". . . from the . . . data, there seems to be a rather strong indication that students who elect to study chemistry achieve no greater success in chemistry than do those students who take it as a requirement."

2. The data "seem . . . to indicate that there may be some tendency for the less intelligent students not to elect to take chemistry."

UNIT V

Problem.—To determine whether chemical information is retained after the study of chemistry in high school.

Method.—The scores made by the high-school X- and C-groups on the Iowa training test and on the functional test were compared with those of both the college X- and C-groups on the same tests.

Conclusions.—"In so far as the high-school and college groups are comparable," the data indicate "that some residue of chemical information remains after the study of chemistry in high school. The gains on the training test appear to be more permanent than the functional gains." "On the functional test, the gains seem less permanent, if indeed they show any permanence at all."

General Conclusions.—1. "The study of chemistry for one year in high school yields significant, measurable, and relatively permanent gains in the knowledge of chemistry."

2. "Growth in knowledge of chemistry is accompanied by significant but smaller gains in the ability to apply this knowledge."

3. "Retention of the facts of chemistry is sustained over a longer period than is the ability to apply the facts."

4. "Both the acquisition of knowledge of chemistry and the ability to apply such knowledge are largely the resultants of instruction in chemistry."

STUDY NO. 201

Methods of Recording Laboratory Notes in High-school Chemistry[1]

By L. W. Applegarth*

Problem.—To determine the relative "effectiveness of three methods of recording laboratory notes in high-school chemistry."

Method.—Each of three classes in chemistry in the Whiting Senior High School, of Whiting, Indiana, was divided into two sections. Each section recorded its laboratory notes in accordance with one of three methods: "Method I consisted of answering all questions, writing equations, and following all directions in the laboratory manual during the experiment," and then of writing a connected account "on theme paper in the classroom on the following day. This account of the experiment was written under the following divisions: title, apparatus, materials, observation and data, and conclusion. No drawings were permitted."

"Method II consisted of answering all questions, writing equations, and following all directions in the laboratory manual during the experiment. No further notes were prepared in this method. No drawings were permitted."

Method III consisted of answering all questions, writing equations, and following all directions in the laboratory manual during the experiment and of then completing in the classroom on the following day a written exercise consisting of a small

[1] Compare this study with that of Stubbs, *Investigations in the Teaching of Science*, Vol. II, pp. 317–320.

* *Science Education*, XIX (October, 1935), 107–112.

number of questions and suggestions designed to emphasize the important parts of the experiment. No drawings were permitted.

"The common factor in these three methods consisted of answering all questions, writing equations, and following directions in the laboratory manual during the experiment. The experimental factor was the method of recording. A permanent notebook was kept in Method I, no notes were kept in Method II, and study questions were answered in Method III."

The pupils of the various groups were paired on five bases: grade classification, chronological age, first-semester grade in chemistry; I.Q. (determined from scores on the Henmon-Nelson Test of Mental Ability, Form A, and the Otis Self-administering Test of Mental Ability, Higher Examination, Form B), and sex. "In the first class, Method I was compared with Method II; in the second class, Method I was compared with Method III; in the third class, Method II was compared with Method III."

"Paired students worked as laboratory partners in order to increase the chances of gaining equal information from the experiment.[1] All sections were given exactly the same reading assignment. The method and content of each discussion were kept as nearly constant as possible through reference to the teacher's written notes on the plan of the discussion. Student's written work was done in the classroom under the immediate supervision of the teacher. The source of information consisted of notes in the laboratory guide taken at the time the experiment was performed. Notebooks were kept in the laboratory."

Twenty-six experiments were performed and reported by each group. A test for each experiment was constructed consisting of 10 "items of the blank-space type designed to

[1] Compare this statement with the conclusions of Carpenter and Bowers, *Investigations in the Teaching of Science*, Vol. II, p. 287.

measure the retention of factual materials such as the names of formulas, formulas for chemical compounds, methods of procedure, chemical reactions, and preparation and properties of substances."

"All sections were given the same test on the same day one week after each experiment had been done. In the meantime, written work as required by the different methods had been completed according to schedule. Three weeks subsequent to the performing of each experiment, the same test was repeated to measure delayed retention."

The mean of the 26 mean scores on the tests was determined for each method. The probable error of these resulting means was next computed.[1] The significance of the difference between two of these means was then determined by dividing their difference by the P.E. of their difference.[2] Also a comparison was made, for both immediate recall and delayed recall, of the percentages of individual scores which were favorable to the different methods of recording laboratory notes among high, medium, and low I.Q. groups.

Conclusions.—1. "The writing of a permanent notebook does not increase immediate or delayed retention of facts for an average class consisting of high, medium, and low I.Q. students."

2. "The permanent notebook is used to advantage by a larger per cent of low I.Q. students than it is by high or medium I.Q. students."

3. "For the average class consisting of high, medium, and low I.Q. students, a written exercise, in which the student answers questions designed to emphasize the important parts of an experiment, is as effective as a permanent notebook."

4. "For the average class, the method of writing answers to questions designed to emphasize the important parts of an

[1] $\text{P.E.}_M = .6745\frac{\text{S.D}}{\sqrt{N}}$.

[2] $\text{P.E. Diff.}_M = \sqrt{(\text{P.E.}_{M_1})^2 + (\text{P.E.}_{M_2})^2}$.

experiment increases immediate and delayed retention of facts."

5. "The method of writing answers to questions is used to advantage by a larger per cent of low I.Q. students than it is by high or medium I.Q. students."

6. "The writing of detail notes is not justified for all students. The method is helpful to low I.Q. students."

STUDY NO. 202

An Experimental Comparison of the Daily-assignment-daily-recitation and a Unit-assignment in High-school Chemistry[1]

By Harl R. Douglass* and George H. Fields

Problem.—To determine the relative efficiency of a daily-assignment plan and a large-unit assignment plan of teaching.

Method.—The course in high-school chemistry was divided into 14 related units "of sufficient length to require from two to four weeks each for completion." "A typical unit included (1) a general outline of the work embraced by the unit; (2) a list of readings on the topic . . . taken mostly from chemistry texts although other science books and articles were also used; (3) a list of special topics of general interest, such as, photography or matches, together with references; and (4) a list of optional experiments. All assignments were mimeographed."

"At the beginning of the study of a unit, a day (or more if necessary) was taken up with a general discussion of the unit and the problems involved provoking discussions of the things included in the unit. Pupils were then put on their own responsibility for finding and assimilating the assigned material. Reference books were available in the classroom and

[1] Compare this study with that of Atkins, pp. 95–99 of this volume.

* *Science Education*, XX (October, 1936), 141–145.

the entire class period for several days, varying with the length of the unit and its difficulty, was given over to study. During this time the pupils were urged to bring to the instructor for solution or discussion, any problems that they had found too difficult for them alone. After sufficient time had elapsed for all students to read the references and to do the assigned laboratory work a class period or more was devoted to another general discussion of the unit and its special topics. Special difficulties were noted and smoothed out. Following this, a test was given over the unit."

"In the sections using the daily-assignment-daily-recitation method, subject matter was assigned in such units that one could be covered in a single recitation period. Every effort was made to make the breaks in the chapters at logical points so that no disadvantage would arise from an illogical division. Written assignments were made for this group so that no difference would result from a more definite assignment in the other group. Since the double-period plan of supervised study is used in this school, both groups had the same opportunity to consult with the instructor about their individual difficulties during the study periods. The daily discussions brought out the group discussion and the group problems. Topics suggested as collateral reading for the unit-assignment group were here given as special reports. The usual recitation consisted of discussion by the pupils of the material in the assignment, oral reports by pupils, on special topics, and supplementary discussion by the instructor of important points not brought out by the pupils."

"Every effort was made to narrow the variable factors down to (1) the length of the assignment, and (2) the responsibility placed on the pupil to get and organize his own material so that he might see, not isolated facts, but a unified whole."

Three separate experiments (designated as Units I, II, and III), were conducted each with a pair of equated groups of respectively 29, 26, and 18 pupils in each group. Approxi-

mately the same pupils, re-paired, continued in Unit II after the completion of Unit I; their final test-scores in Unit I were used as initial test-scores in Unit II. Entirely different pupils were used in Unit III. These pairs of groups were equated from six classes of chemistry in the West Waterloo (Iowa) High School, on the bases of sex, school classification, chronological age, and I.Q. (as measured on the Terman Group Test of Mental Ability). "Paired individuals were of the same sex and school classification. Due to scheduling difficulties, it was not possible to shift pupils in order to balance the sections either in size or any other factor. This together with the method of equating the experimental groups, necessitated dropping from the experiment those students who were at the extremes in I.Q. and age, as well as several who were of odd classification or repeaters. All pupils considered in the experiment were either Juniors or Seniors." The paired groups in Unit I had had no previous training in chemistry; those in Units II and III had had one semester of chemistry.

Achievement in all three units was measured by scores on the Powers General Chemistry Test, Form B; and for Unit III by scores, also, on a test constructed by one of the authors (Fields). This latter test consisted of 100 items measuring information and ability to write equations and formulas, and to solve problems. "The reliability of one-half the test was found to be .85 ± .008, by the method of odds and evens which when stepped up to give the reliability of the whole test, by the Spearman-Brown Formula, became approximately .92 ± .01."

Relative progress of the groups was measured in terms of gain, of final status, and of per cent of possible gain. The reliability of the indicated differences in gains was determined by dividing the differences in means by $S.D._d$.[1]

[1] "$S.D._d = \sqrt{S.D.^2_{m_1} + S.D.^2_{m_2} - 2r_{m_1m_2}\, S.D._{m_1} S.D._{m_2}}$. In this formula $r_{m_1m_2}$ is assumed to be approximately equivalent to $r_{g_1g_2}$, the correlation between the gains . . ."

Conclusions.—1. "Neither method seems to be distinctly superior or to produce consistently better achievement in high-school chemistry classes regardless of the personnel of the group."

2. "The evidence seems to indicate a greater probability that the unit-assignment may result in slightly better achievement than the daily-assignment-and-recitation."

3. "Factors other than method are responsible for most of the superiority shown in achievement by one of a pair of individual pupils."

4. "The evidence is not at all conclusive that achievement by either method shows a higher correlation with I.Q., but data favor the unit-assignment."

5. "The unit-assignment is at least equal to the daily-assignment-and-recitation as a means of imparting information about chemistry, and, if it has other unmeasurable benefits not possessed by the daily-recitation, is worthy of a trial."

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STUDY NO. 203

The Selection, Organization, and Evaluation of Localities Available for Unspecialized Field Work in Earth Science in the New York City Region

By Herbert J. Arnold*

UNIT I

Problem.—"To select major generalizations from the field of geology which may be of interest to liberally educated persons."

Method.—This study was based upon two fundamental assumptions which were given some justification from an analysis of pertinent sources:

From the point of view of general education, certain of the generalizations developed through the work of geologists belong among the major generalizations and principles of science.

Field trips may be of value in the development of an understanding of these generalizations, at all grade levels.

In determining the major generalizations of geological science, the methods and techniques of Craig,[1] Billig,[2] Pruitt,[3] and Billings[4] were used "with whatever modifications or refinements were necessary in the selection of these major generalizations." Fifteen books were selected for analysis for principles, on the basis of these criteria:

* Dissertation for the degree of Doctor of Philosophy, Teachers College, Columbia University. Copies may be secured from the investigator, Teachers College, Columbia University, New York City. Only the portions of this study possessing general interest and application are here included.

[1] *Investigations in the Teaching of Science*, Vol. II, pp. 40–52.

[2] *Ibid.*, pp. 374–380.

[3] This volume, pp. 153–163.

[4] Neal Billings, *A Determination of Generalizations Basic to the Social Studies Curriculum*, University Research Monograph 11 (Baltimore: Warwick and York, 1929).

The book must have been reviewed in the *Scientific Book Club Review* (first published in 1930)

It must be geological in character

It must be non-technical as judged from the fact that it did not contain "so many technical terms as to make it difficult for a layman to get the thought of sentences or paragraphs," and it did not contain "mathematical formulae or equations to illustrate points in the text"

The name of its author, if he be an American, must be included in *American Men of Science;* and if he be of foreign nationality, in *Who's Who*

On the basis of these criteria, 15 books on geology, written for the general reader, were chosen together with seven others published between 1925 and 1930, which satisfied all the criteria except the first.

A statement from one of these books was considered to be a scientific generalization provided it satisfied the first four of the seven criteria used by Pruitt.[1] In the search for statements of principles, 5,501 pages were read in the 22 books. Each generalization as it was discovered was written on a card, together with the page reference. A separate set of cards was assembled for each book. "In this way any special emphasis given to a generalization by an author was preserved, as well as any particularly choice phrasing. . . . Only one card was written for a given generalization in the analysis of one book . . . more than one page reference was noted, if necessary, on the card." The authors' words were used except that "remarks about specific localities in most instances were made general, compound statements of generalizations were in many cases made simple," and "where no generalized statement was given by an author, one was written."

"As the cards accumulated from the book analysis they were filed under some appropriate heading—such as *fossils*, *weathering*, *vulcanism*, etc."

Cards bearing the same or similar generalizations were grouped in packs and studied in order to select "the most accurate, most inclusive, or most clearly worded statement express-

[1] Pruitt, *op. cit.*

ing the generalization." "In case no card in the pack contained an adequate statement, one was carefully formulated." The number of authors who used the given generalization was recorded as the frequency of the generalization. Whenever a statement contributed to two or more generalizations, "both of these generalizations were kept, but the authors mentioning the less general one were counted in determining the frequency of the more general statement." "All of the frequency counts were carefully checked by a person competent to judge the logic involved in including a less general statement under a more general one."

The list of generalizations was compared with a standard two-volume textbook of geology. All but one were found among those obtained from this textbook. It was found, however, that "there was a greater number of geological terms used in the generalizations from the textbooks, i.e., there was a greater number of definitional generalizations," and that "the generalizations from the textbook expressed greater detail than those from the popular books."

A comparison was also made of these generalizations with the list of geological concepts reported by Warriner.[1]

Findings.—1. "A total of 2,128 cards bearing generalizations were written." The smallest number from a book was eight; the largest 342.

A sample of the outline of geological generalizations determined from the investigation follows:

PRINCIPLES OF GEOLOGY

I. Gradation

The agents of erosion wear down the high regions of the earth (15).[2] The surface of the earth is carved and sculptured by the agents of erosion

[1] C. C. Warriner, The Geology of General Science as Determined by the Geology Found in Magazines and Newspapers. Master's Thesis (unpublished), Iowa State University, 1926.

[2] The numbers in parentheses indicate the respective numbers of books among those analyzed, in which the various generalizations are found.

(5). The agents of erosion are wind, water, and ice (5).

1. Weathering causes the break-up of rock (8).
   a. Rock may be broken by temperature change (4).
   b. Rock may be broken by water in cracks expanding upon freezing (7).
   c. Rock may be broken by growing roots of plants which have penetrated cracks (4).
   d. The atmosphere decomposes rock chemically and causes it to crumble (5).
   e. As cliffs wear back, talus slopes are formed (5).
   f. Soil is produced by the weathering and decomposition of rock (10).
2. Wind, carrying sand, sculptures and erodes the earth's surface (10).
   a. Wind erosion is most active in arid regions (3).
   b. Sand dunes are heaped up and are shifted by the wind (4).
   c. Dust may be transported by the wind (6). Dust transported and deposited by the wind forms loess (4).

UNIT II

Problem.—To develop a technique for the selection of localities and materials suitable for the illustration of generalizations or principles of geology.

Method.—The geological literature dealing with the region being studied was carefully read, and a card catalog was compiled of localities where geological principles might be illustrated. Because of the large number of such localities to be examined, the places actually visited were selected on the following bases:

The localities were included in city, county, and state parks

They were indicated as being particularly worth examining by the words in which they were described in the literature

They were accidentally encountered in visiting the places already chosen to be visited

They were deliberately sought out because they illustrated geological generalizations in the outline, which had not yet been illustrated by the places selected on the basis of the previous criteria

As each locality was visited and examined it was evaluated on the following bases:

I. Ease of getting to the place
   3. Easily accessible; approachable to within a quarter mile by rapid transit line, bus line, or railroad
   2. Accessible; approachable to within a quarter mile by private car or chartered bus
   1. Comparatively inaccessible; requiring walking of more than a quarter mile

II. Permanence of features to be observed
   3. Permanent; features in parks and museums
   2. Probably permanent; river gorges, beaches, road-cuts in the country, quarries and mines (both abandoned and in operation)
   1. Probably temporary; excavations for buildings

III. Ease and clarity of observation
   3. Seen with ease by any one
   2. Seen with difficulty because of obscuring matter, such as vegetation, or haze
   1. Seen with difficulty because of the difficult and involved nature of the observations themselves[1]

STUDY NO. 204

A Critique for the Evaluation and Development of Science Courses of Study for the Pre-college Years

By Philip Gustaf Johnson*

UNIT I

Problem.—To trace the historical development of courses of study for the teaching of science in the elementary school, the junior high school, and the senior high school.

[1] The remainder of this publication is devoted chiefly to a rather complete description of the localities within fifty miles of New York City at which the geological generalizations selected may be illustrated, an explanation of the special features to be seen at each place, and an evaluation of the location in terms of accessibility, permanence, and ease and clarity of observation.

* Unpublished dissertation for the degree of Doctor of Philosophy. Cornell University, 1933.

Method.—An analysis was made of a large number of articles and reports in educational periodicals and books, and of reports of state superintendents, to determine the significant trends in the development of courses of study in science for the pre-college levels.

Findings.—1. The development of courses of study in science for the elementary school has followed four general stages: (a) Introduction, characterized by a few diverse beginnings; (b) Rapid Development, characterized by considerable diversity with respect to content and organization but in general conforming to a few characteristic and distinct types; (c) Reaction, characterized by a movement toward greater uniformity with respect to content and organization; and (d) Analysis, characterized by the introduction of content and organization based on specific objectives. A Concept Period characterized by an organization based on principles of science is beginning.

2. The organization of courses of study in science for the secondary school has developed through three periods: (a) a topical organization, characterized by the logical organization of course content; (b) an organization in terms of specific objectives, characterized by the statement of desired outcomes along with a more or less logical organization of content designed to achieve these outcomes; and (c) a unit organization characterized by a wide diversity of interpretations of what constitutes a unit, and including an organization based on scientific principles and concepts. Courses of study for the early secondary school levels have evolved more rapidly through these periods than have those for physics and chemistry.

UNIT II

Problem.—To determine the extent to which the judgments of teachers regarding the development, organization, and content of courses of study in science, and methods of teaching

science at pre-college levels are influenced by the teaching experience, science preparation, and professional preparation of these teachers.

Method.—An extensive survey was made of professional literature, including many courses of study, to ascertain the various plans for developing and organizing content, and the various suggestions relative to teaching methods. Typical plans, schemes of organization, general content, and teaching methods were described in short statements and arranged in lists of closely related items. These were submitted to six selected juries composed respectively of rural, elementary-city, junior-high-school, and senior-high-school teachers, supervisors of science, and leaders in science education, with the request that they approve or disapprove each item. The evaluators were also asked to furnish information concerning their own teaching experience, science preparation, and professional preparation. Those within each of the six groups who submitted answers, further grouped into "low" (those in the lowest quartile), "medium" (those of the middle 50 per cent), and "high" (those in the upper quartile) groups on the basis of each of these three factors and the responses of each group, were summarized and compared. A total of 240 judges were involved in this unit of the study.

Findings.—1. Rural-school and junior-high-school teachers with high subject-matter and professional preparation favored a plan whereby the state would distribute suggestions for use by teachers in preparing their own courses of study. Supervisors and leaders in science education favored the preparation and distribution of courses of study by the state. Elementary-city and senior-high-school teachers revealed little or no tendency to be influenced in their attitudes towards the preparation of courses of study by their experience or their subject-matter preparation.

2. The amount of experience appeared to have but little influence on the content desired in courses in science. The

usual sections, "as those devoted to aims and objectives, methods, suggestions for various grades, and the like," were favored except those relating to administrative details and the characteristics of a teacher. Junior-high-school teachers with high professional preparation favored courses of study which provided much factual information while senior-high-school teachers with high science preparation favored the inclusion of examples of effective teaching plans. Supervisors with high professional preparation favored the inclusion of suggestions of basic content and optional materials while those with high science preparation favored suggestions for effective administration of the courses as well as for factual information to be included.

3. The contributors did not favor definitely the general utility[1] of science courses of study. The construction of science courses of study which would be generally useful in schools of different types of organization was favored by a comparatively larger percentage of supervisors and leaders in science education than of any other groups. Rural-school teachers favored the state preparation of junior-high-school courses of study which would be useful for the seventh and eighth grades of a rural school.

UNIT III

Problem.—To determine the nature and value of specific items of content, and plans for development and organization of courses of science at pre-college levels.

Method.—Two hundred twenty-three statements of principles and of philosophy governing the selection of con-

[1] "General utility refers to the use of a course of study in different schools, i.e., the use of elementary-city courses of study in rural schools and *vice versa;* the use of a VII–XII general-science course of study in the seventh or eighth grades in a rural school or in an elementary school on the I–VIII plan, as well as in the ninth grade of a high school on the IX–XII plan."

tent, and 82 similar statements governing the development and organization of content were described in short statements. These statements, organized in related sections, were evaluated with respect to their "idealness" and "helpfulness," by a large number of qualified teachers, supervisors, and experts, including 47 per cent of the respondents of Unit II.

Findings.—The following statements represent guiding principles and philosophy which many evaluators judged to be ideal or very helpful:

Course-of-study suggestions for science teaching should be organized in several loose-leaf publications. These should be arranged to fit into a common folder and supplements or revised sheets issued from time to time.

The general aims should be discussed in the early part of the publication and the specific aims interwoven with the suggested subject matter and methods.

The science subject matter should be organized separately with occasional correlation with other subjects.

The subject matter within the science course should have its organization based on pupil needs and interests; the teacher to sense these and guide the development of the subject-matter material.

The methods should be discussed entirely in connection with the subject-matter material, i.e., the subject-matter divisions followed by a discussion of suitable methods.

The references should be placed both in connection with the parts to which they relate and in an organized list.

The bibliography should contain the name of the author, title, publishing company, price, and a brief statement or abstract indicating the contents of the reference.

The suggested subject matter and methods should be interesting or capable of being made interesting; should be suited to the pupil's level of accomplishment; should be based on the pupil's previous science experiences; should be adapted to the school organization; should be concerned with the "at home" elements of science; should be based on research; should provide for much pupil activity; should seek to develop principles rather than present more or less isolated facts; should be different for a rural school from those of a city school; should simplify the problems of supervision; and should make science experiences available for all pupils.

The science committee for science course-of-study development should involve the co-operation of educational advisers, teachers of science in public schools and in normal schools and colleges, and supervisors in school systems and training institutions.

UNIT IV

Problem.—To assemble statements of philosophy and guiding principles for ready reference.

Method.—"An analysis was made of materials in seven yearbooks and special reports of committees. Statements of philosophy and guiding principles were copied and listed in the various pre-college groups as indicated by the context in which the statement was found."

Findings.—Forty-five statements were obtained and classified. Samples of the statements follow:

The material should belong to the activities and experiences of childhood, and to the child's biological and physical environment, leading from the familiar to the unknown.

The committee suggests that differentiation (for groups of differing abilities) should be based on the amount and kind of work done with each topic rather than upon a distribution of topics.

Repetition of a subject is not to be condemned when new types and new problems are used to satisfy the broadening interests of children. . . . The high-school teacher should recognize after eight or nine years' work in the grades, that the laws of Nature and Life have been taught.

The junior-high-school pupil is living in the age of hero-worship and the science course of study may well be presented largely in terms of biographies.

It is proposed that the curriculum in science for a program of general education should be organized about large objectives, that understanding and enlargement of these objectives shall constitute the contribution of science teaching to the ultimate aim of education, and that the course of study be so organized that each succeeding grade level shall present an increasingly enlarged and increasingly mature development of the objectives.

It is suggested that we may expect to accomplish a grade placement of materials relating to this objective by analyzing the major generalization into the smaller generalizations, principles, and concepts from which it

has been synthesized and by subsequent subdivision of these until they are reduced to elements which are appropriate for the different grades.

The science of the elementary school should be well-balanced and derived from the major fields of science. It should, however, not be organized or treated about the separate sciences, but rather about the problems and situations which are challenging, many of which may integrate the separate fields.

The science course of the new high school should develop a definite sequence from year to year and from one unit of instruction to the next so that the pupils as they progress through the school will meet problems of increasing difficulty and build continuously on that which has gone before and in relation to that which is to come. . . . The science work of the high school needs to be fully integrated with the science taught in the elementary school, and with the instruction that is to follow later at the college level.

Curriculum organization and content (of rural schools) have been and are formal and unrelated to the life of the child, community, or society, while the environment abounds with vital material. It is organized upon the subject-to-be-learned basis, while the child's life has been teeming with potentially educative activities and experiences.

From the point of view of supervision, the course of study is the point of attack upon subject matter, method, technique, and device for the determination of pupil achievement and of the creative leadership and growth of the supervisor.

STUDY NO. 205

A Study of the Objectives and the Sequence of Courses of Science in the Junior, and Senior High School

By George W. Hunter*

UNIT I

Problem.—To determine the curricular tendencies with respect to science, as indicated by a study of practices in representative American high schools.

* This is the third of a series of studies of which the first was conducted in 1908 and reported under the title, "The Methods, Content, and Purposes of Biologic Science in the Secondary Schools of the United States,"

Method.—In 1930 a questionnaire was sent to three groups of secondary schools: (1) the 500 schools to which the questionnaire for the original study had been sent in 1908 and to which the questionnaire for the second study had been sent in 1923; (2) the 500 additional schools to which the questionnaire had been sent in 1923; and (3) 500 of the leading junior high schools of the country. "This questionnaire . . . asked questions with reference to aims of science at the different age levels, the placement of courses with total offerings in terms of weeks, hours per week and laboratory hours, the sequence of science in the school or school system, the enrollment today as compared with that of twenty years ago, the methods used in teaching, and numerous other questions relating more directly to life science. Replies were received from 528 schools, 209 being junior high schools, 119 three-year senior high schools, and 203 four-year senior high schools," which together represented "a fair sampling of the better large and small city high schools together with a fair number of the better consolidated rural high schools . . ."

Findings and Conclusions.—1. "General science, as such, was practically unknown in 1908."

2. ". . . the number of hours devoted to science is much more stabilized than in the past."

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in *School Science and Mathematics*, X (January and February, 1910), 1–10 and 103–111. The second, conducted in 1923, was reported under the title, "The Place of Science in the Secondary School," in *The School Review*, XXXIII (May and June, 1925), 370–381 and 453–466; and as, "Is There a Sequence in Secondary Science?" in *School and Society*, XX (December 13, 1924), 762–766 (See *Investigations in the Teaching of Science*, Vol. II, pp. 309–312). Unit I of this third study is reported under the title, "The Sequence of Science in the Junior and Senior High School" in *Science Education*, XVI (December, 1931), 103–115; and as "Science Sequence in the Junior and Senior High Schools" in *School Science and Mathematics*, XXXIII (February, 1933), 214–223. Unit II is published in collaboration with Roy Knapp under the title, "Science Objectives at the Junior- and Senior-High-School Level," in *Science Education*, XVI (October, 1932), 407–416.

3. " 'Book' courses, except in physiology and hygiene, have largely disappeared."

4. "Junior-high-school science courses usually have from three to five periods a week with much more relative emphasis on demonstration than on laboratory work."

5. "The movement to do away with double periods in the senior high school is not greatly evidenced by figures, most schools reporting two double periods per week for the tenth, eleventh, and twelfth year science."

6. General science in the ninth grade "is changing in its curricular material, for instead of emphasis being placed on the earth science or physical sciences, the tendency now seems to be to emphasize the biological aspect, especially as that phase affects the conservation of health and wealth."

7. ". . . while the top of the curve for general science [in 1930] still appears in the ninth grade, a very considerable number of courses are given in the seventh and eighth grades. Many school systems, especially in larger cities, have definitely worked out a three-year sequence of science for the seventh, eighth, and ninth grades in the junior high school. In such sequences we usually find the seventh grade giving from two to four periods a week, the eighth grade receiving about the same number of hours, while in the ninth grade the median appears to be five hours a week." "The distribution of general science courses seems countrywide . . ."

8. ". . . hygiene as such has had a phenomenal growth in this country during the past decade" and "is appearing not only in the junior high school but to a much larger extent in the senior high school than in former times. . . . the emphasis on health education is making its way from the elementary school up into the junior high school and into the senior high school. In many school systems distinct emphasis is being placed on the teaching of health habits at the seventh-grade level."

9. ". . . general biology is still firmly ensconced in the tenth grade. Although there appears to be a distinct tendency

toward a movement downward in certain states, perhaps it would be more correct to say that this tendency is a spread in both directions . . . Many school systems are opening up their courses in biology to students in the tenth, eleventh, and twelfth grades."

10. "The situation with reference to the chemistry-physics sequence is still unsettled, some states preferring chemistry in the eleventh year followed by physics, and other states preferring just the opposite sequence." There is in general, however, an indication of a "trend to place chemistry before physics in the sequence in the four-year high school and in the three-year high school."

11. The number taking chemistry "in the larger schools far exceeds the number taking physics while the numbers taking the two subjects in the smaller schools are more nearly equal." "Probably at least twice as many pupils are taking biology in tenth year as are taking chemistry or physics in the eleventh and twelfth years."

12. There is a "tendency toward dropping out of the special sciences. There has been a noticeable decrease in botany and zoology since the publication of the last questionnaire in 1923." Physiography has lost "proportionately more than any other of the special sciences." "Human physiology . . . has shown a distinct decrease except in the twelfth year . . . Hygiene has supplanted human physiology, especially in the lower years of senior high school, . . ."

13. "Enrollment in the special sciences is relatively small, botany, human physiology, physiography, zoology, astronomy and geology apparently ranking in the order given. Two new sciences appear, namely, bacteriology and psychology, but the offerings are few and the number of students enrolled is very small."

14. ". . . a much greater proportionate number of students are taking science courses now than twenty years ago. Most of the increase comes with the junior-high-school science, but

a considerable portion of it comes in the ninth and tenth grades."

15. Of the respondents, 209 said that chemistry and physics gain considerably from the earlier science courses, 116 stated that there is little gain, and 18 that there is no gain. "The respects in which the gains were made are specifically as follows: Backgrounds, fundamental concepts in the field of science (132),[1] increased interests (56), improved method of attack, ability to use the method of science, problem solving (51); attitudes, skills (32); terminology, nomenclature (29); laboratory techniques (24); exploration, survey of field, orientation (23); ability to evaluate evidence, scientific thinking, clearer thinking (15)"; and "information, acquisition of facts, greater powers of observation, increasing experience, breadth of view, appreciations, and larger science enrollment." "In most of the schools which said there was little gain, from the work previously given, there was a falling off of enrollment in physics and chemistry."

16. In answer to the question, " 'Are the science courses more closely related to other courses in the secondary school than they were twenty years ago?' 299 said that there was a greater correlation; 31, no correlation; and 14 said very little, or qualified their answers."

UNIT II

Problem.—To determine "the 'real objectives' of the teachers of science in the secondary school."

Method.—This section of the questionnaire "was filled in for the junior-high-school level by 114 schools, for the senior-high-school level by 115 schools, and for both levels by 117 additional schools." This same questionnaire was also sent to the members of the National Association for Research in

[1] The numbers following these items refer to the frequencies with which the various items were mentioned in the 528 replies to the questionnaire.

TABLE LXXXVIII

RANKINGS OF OBJECTIVES FOR VARIOUS LEVELS OF SCIENCE BY VARIOUS GROUPS

Objective	Rank for science given by		Rank for J.H.S. science given by		Rank for S.H.S. science given by	
	Teachers of J.H.S.	Teachers of S.H.S.	Teachers of J.H.S.	Members, N.A.R.S.T.	Teachers of S.H.S.	Members, N.A.R.S.T.
To understand environment	1	4	1	5	4	3
To explore the field of science	2	18	2	9	17	6
To arouse interest in science	3	7	3	3	7	17
Knowledge of environment	4	9	4	18	9	11
To give information	5	2	5	5	2	8
To master scientific method	6	3	6	5	3	1
To explore pupil's interests	7	11	7	1	11	11
Appreciation of environment	8	12	8	2	12	11
To develop appreciation of value of health	9	10	9	12	10	
Propaedeutic functions	10	1	10	9	1	6
To arouse interest in environment	11	13	11		7	
Development of powers, observations, etc	12	14	12	14	13	
Worthy use of leisure	13	16	13	18	16	17
To establish scientific thinking habits	14	6	14	12	6	6
To develop a scientific attitude toward all problems	15	8	15	7	8	2
To develop skill in doing useful tasks	16	5	16		5	4
To give basic experience				9		
To develop appreciation of the work of scientists	19	15	19	12	15	11

Science Teaching, a large percentage of whom submitted aims for both the junior- and senior-high-school levels.

The various aims were classified into four groups: those submitted by the teachers of junior-high-school science, those by the teachers of senior-high-school science, and those submitted by the members of the N.A.R.S.T. for junior- and also for senior-high-school science.

Findings.—"In so far as aims are a criteria of actual work being done, . . . teachers of junior-high-school science are doing their work better and with more understanding than teachers of the senior high school. Teachers of neither level show much evidence of humanizing science through the development of an appreciation of the work of scientists. Teachers of the upper level seem to be held more closely by convention and college requirements, there appearing to be but little relationship between the major aims of the two levels."

The objectives of science for various levels with their rankings by various groups are shown in Table LXXXVIII.

STUDY NO. 206

The Teaching of Science in Secondary Schools of the North Central Association

By Francis D. Curtis*

Problem.—To ascertain the actual conditions and practices existing with respect to the teaching of science in the secondary schools accredited by the North Central Association.

Method.—During the spring of 1930 the investigator prepared an extensive list of items of information which it seemed desirable to secure, with respect to the teaching of science in a

* *North Central Association Quarterly*, VI (March, 1932), 433–474. The report which follows is chiefly the summary of this study which appears in *Science Education*, XVII (February, 1933), 1–11.

group of highly selected secondary schools. After discussing this list with several members of the Executive Committee of the North Central Association and with various teachers of science, in order to make sure that the list was sufficiently complete, and that every item contained was of sufficient importance to warrant its inclusion, the investigator prepared a tentative draft of two blanks. The first of these, addressed to the superintendent or principal, included all the general items concerning which information was sought; while the second, addressed to the teacher of science, included all the specific items. The investigator then secured the co-operation of several heads of secondary schools and of a number of teachers of science in these schools, who consented to test the adequacy of the blanks by filling them out and by making criticisms and suggestions for their improvement. The final forms of the two blanks, which together constituted the complete questionnaire used in this investigation, were prepared by revising the trial drafts in the light of the criticisms and suggestions submitted.

This questionnaire was sent to the 2,167 secondary schools of the North Central Association. Returns were received from 1,802, or 83.1 per cent of these schools, and from 5,481 teachers of one or more classes of science in these schools.

Findings.—1. *Grade Placement of Science Courses.*—Agriculture was taught in 738 or 41.6 per cent of these schools. This subject was found in all the grades from the seventh to the twelfth, although, on the whole, in those schools in which registration in this subject was restricted to a single grade, agriculture was scheduled most often in the tenth.

Astronomy was found in only 22 or 1.1 per cent of the schools. It was distinctly an upper-grade subject.

Elementary biology was listed in the replies from 260 or 14.6 per cent, and advanced biology in the replies from 923 or 52.1 per cent of these schools. In a large majority of the schools of every group the study of biology was restricted to

pupils of a single grade, usually of the tenth, though not infrequently of the ninth, the eleventh, and, in sporadic instances, the twelfth. In certain schools of every group, however, the classes in biology were made up of pupils of more than one grade, usually of the tenth and eleventh, or of the upper three grades.

Botany and zoology were listed, respectively, in the reports from 308 or 17.4 and 191 or 10.8 per cent of these schools. In general the placement of these subjects followed the practices indicated with respect to biology.

Chemistry was listed in the replies from 1,251 or 70.6 per cent of the schools. It seems likely, however, that both this percentage and the percentage for physics were somewhat smaller than they should be to represent the total percentages of schools offering these two courses, because in many small schools chemistry and physics are offered in alternate years. In some of these schools, therefore, either chemistry or physics may have been omitted in the reports because it was not being taught at the time the questionnaire was answered, although it actually had a definite place in the science curriculum of the school.

Chemistry was found to be definitely an upper-grade subject, since it was offered below the eleventh grade in a negligible number of schools.

General Science appeared in the science curricula of 1,199 or 76.7 per cent of the schools. The fact, however, that general science is offered below the ninth grade in a considerable number of school systems organized on the 8-4 plan renders this percentage too small to indicate truly the extent to which that subject was taught in the cities represented by these schools of the Association.

Geology was offered in 55 or 3.1 per cent of the schools and these schools are located chiefly in the mountain states, Colorado and Montana. This subject was confined almost wholly to the eleventh and twelfth grades.

Hygiene was found as a separate subject in 399 or 22.5 per cent of the schools. In these, the subject had no definite placement; it was scheduled in all the grades from the seventh through the twelfth, and was found with about equal frequency in all these grades.

Physics appeared in the science curricula of 1,589 or 89.7 per cent of the schools. Like chemistry, physics was found to be distinctly an upper-grade subject and its study to be limited almost wholly to pupils of the eleventh and twelfth grades.

Physiography was reported in the replies from 311 or 17.6 per cent of the schools; in these it was regarded chiefly as a subject for the upper high-school grades.

Physiology appeared as a separate subject in the reports of 521 or 29.3 per cent of the schools. Almost exactly half of the schools reporting physiology, however, are located in Illionis, in which state one-half unit of physiology is required by law to be taught in all high schools. This subject seems to have no definite grade placement.

Miscellaneous courses. Sanitation was found in the curricula of three of the schools, while mining, household chemistry, metallurgy, bacteriology, applied science, qualitative analysis, elementary science and elementary physical science (as distinguished from the conventional general science), and photography were each found in the science curriculum of a single school.

Summary. The data of this study indicate that only four science courses were found in a majority of these high schools. Further, although there were many exceptions within the various groups, on the whole these four subjects had a definite grade placement and may be said to have constituted, for the four-year high school at least, a definite sequence. This sequence included general science in the ninth grade, biology in the tenth grade, and physics and chemistry in the eleventh and the twelfth grades.

2. *Courses in Science Required for Graduation.*—The numbers of years of science required for graduation ranged in the various

schools from none whatever to six years. In 52.7 per cent, or in slightly more than half the schools, one year was required, while in 30.0 per cent of the schools two years were required. All but 6.8 per cent required one or more years of science for graduation.

Practically every science course listed was a requirement in some school or schools. In those schools in which the requirement for graduation was more than a single year, there were nearly two hundred different combinations of required science courses. Most of these requirements were stated specifically, though in most schools some latitude of choice was allowed among several designated courses. In 7.9 per cent of the schools, however, the pupil was permitted to choose any course in science offered.

The four major courses, namely, general science, biology, physics, and chemistry, were required more frequently than any of the others. Chemistry and physics were more often found listed among the required courses than biology, while these three "laboratory courses" were required somewhat more frequently than general science. Of the minor subjects, only hygiene, agriculture, botany, zoology, and physiology were in any cases given major emphasis; that is, were named first in the statement of required courses in science.

3. *Salaries.*—The salaries which these science teachers received ranged from no actual money whatever, in the cases of 153 men and women (who were teaching in parochial schools and who constituted 1.1 per cent of the men and 7.0 of the women reporting this item), to more than $4,500 for certain administrators who taught one or more classes of science, or for certain college and university teachers who combined high-school teaching with junior-college or university teaching.

The smallest salary received by any full-time teacher of science was that of one woman who reported $720 for her year's work. Only .5 per cent of the women and .3 per cent of the men, or .4 per cent of all these teachers, received salaries of less than $1,000.

On the whole, the men were much better paid than the women, though there was found to be a considerable overlapping of the salary-ranges for the two sexes. The modal number of women teachers, 551 or 34.5 per cent, received between $1,251 and $1,500; the modal number of men, 776 or 21.5 per cent, received from $1,751 to $2,000. Exclusive of those in the "no salary" group, 41.0 per cent of the women teachers, but only 11.5 per cent of the men teachers, received salaries of less than $1,501; while 51.8 per cent of the men teachers and only 25.3 of the women teachers received salaries in excess of $2,000.

4. *Official Positions.*—These teachers may be divided into three groups: those (86.8 per cent) whose primary occupation was classroom instruction (classroom teachers, heads of departments, supervisors, and critic teachers); those (8.5 per cent) whose major duty was administration (superintendents, principals, assistant-principals or vice-principals, and deans); and those (4.8 per cent) whose chief responsibility was the coaching of athletics. A more detailed analysis would increase the percentage of the last group at the expense of the first, since some of the heads of departments were also officially in charge of athletics and had as additional duties some teaching, while others had their activities divided between teaching and athletics, but gave "classroom teacher" as their official designation.

Nearly 29 per cent of the teachers responding to this item were heads of departments. An overwhelming majority of these department heads were men, though in the groups of largest schools the numbers of these men and women who were heads of departments were approximately equal. There were 51 different combinations of subjects included in these various departments. Most of these department heads had charge either of departments of science or of one or more branches of science, such as "physics and chemistry," or "biology and general science." A considerable number, however, were heads

of departments which combined one or more branches of science with some other subject having a remote relation or no relation whatever to science. Among such were found "head of science and athletics" and "head of biology and French." There was evident also in these schools some tendency to assign the teaching of science not only to department heads but also to classroom teachers whose major interests and training, as judged from their official positions as named, were totally divorced from science. Thus 3.9 per cent of all the teachers of science were in a group which included heads of modern language, of English, of French, of Spanish, of Latin, of social science, of commerce and athletics, of mathematics, of physical education, and of history.

5. *Teaching Experience.*—A substantial percentage of the teachers had had little or no previous experience in teaching, and a still larger percentage had had meager experience or none whatever in teaching science. Thus, a combination of data shows that 13.0 per cent of the men and 14.7 per cent of the women had had less than two years of teaching experience; and that 17.8 per cent of the men and 25.3 per cent of the women had taught science less than two years. It should be noted, however, that 32.0 per cent of the men and 36.4 per cent of the women had taught for more than 10 years, and that 24.7 per cent of the men and 24.7 per cent of the women had taught *science* for more than 10 years.

The data further show that many of the teachers had taken up the teaching of science after they had had some experience in teaching other subjects; and that considerably more of the women than of the men were in this group; also that the shifting of the teachers from school to school had been even greater than the shifting of teachers from other subjects into science.

A considerable percentage of the teachers had had experience in teaching in the elementary school; not half of these teachers, however, had had experience in teaching elementary science.

A considerable number of these teachers had had experience in teaching in college, university, or normal schools, or were still engaged in teaching in higher institutions of learning.

6. *Degrees.*—The percentages of men and women teachers holding corresponding numbers of degrees were fairly constant. Most of the teachers (76.2 per cent of the men and 78.3 per cent of the women) possessed one degree; most of the remaining teachers (19.4 per cent of the men and 17.1 per cent of the women) had two degrees. Only 2.7 per cent of the men and 1.6 per cent of the women had more than two degrees.

The number of men (1,707) who possessed the B.S. degree was approximately 94 per cent of the number (1,820) who held the A.B. degree; the number of women (640) possessing the B.S. degree, however, was only about 70 per cent of the number (916) possessing the A.B. degree.

Of these teachers, 18.8 per cent of the men and 16.4 of the women possessed advanced degrees. The number of the men (207) who had the M.S. degree was about 43 per cent of the number (441) who had the M.A. degree. The number of the women (84) who held the M.S. degree was about 47 per cent of the number (178) who possessed the M.A. degree.

Only .6 per cent of the men and .3 per cent of the women possessed the Ph.D. degree.

The 116 miscellaneous degrees included B.L., B.Chem., B.S.E., B.M.T., B.Arch., A.A., B.L., B.Ped., and B.U. One was listed merely as B.

Nearly half of the men (47.9 per cent), and exactly a third of the women (33.3 per cent), were pursuing their studies toward advanced degrees. About three-fourths of the men and women who were engaged in work toward higher degrees were studying in summer school; the rest were availing themselves of the opportunities afforded by correspondence courses, extension courses, residence work, and part-time work. A few were engaged only in work upon their theses.

7. *Practice Teaching.*—Only 4.9 per cent of the men and 10.9 per cent of the women had had practice teaching. Of those who had not had practice teaching 76.6 per cent of the men and 77.4 of the women had been permitted to substitute laboratory instruction in college for practice teaching. A negligible percentage of the men and women (respectively .2 and .3 per cent) had been permitted to substitute mere observation of teaching for actual participation in classroom teaching.

The data indicate further that 68.4 per cent of the men and 50.0 per cent of the women had had their practice teaching (or its accepted equivalent) in science. Also, that the practice teaching of the remaining 31.6 per cent of the men and of the 50.0 per cent of the women had been secured in a variety of subjects and subject combinations, more than sixty of which have not the remotest connection with science.

8. *Professional Preparation.*—Sixty-seven and eight-tenths per cent of the men and 65.9 per cent of the women had had between 12 and 30 undergraduate hours of education. Moreover a considerably larger percentage both of men and of women had had in excess of 30 hours than had had fewer than 12 hours.

Of the men, 48.1, and of the women, 61.6 per cent had no graduate credits in education. Moreover, 87.7 per cent of the men and 94.6 per cent of the women had fewer than 31 graduate hours in education. On the whole the men had had, on the average, a somewhat larger number of graduate hours than the women. As with the undergraduate hours, the average number of graduate hours per teacher tended, in general, to increase with the size of the school.

9. *Subject-matter Preparation of All Teachers of Science.*—Of the 3,260 men and 1,247 women who submitted data on this item only 64, or 2.0 per cent, and 16, or 1.3 per cent, respectively, reported that they were teaching classes in science when they had had no previous preparation in the subject matter

of any branch of science. Moreover, 80 per cent of the men and 69.4 per cent of the women had had more than 30 undergraduate hours of preparation in the subject matter of science; also 34.1 per cent of the men and 36.0 per cent of the women had had more or less of graduate work in some branch or branches of science.

10. *Subject-matter Preparation of Teachers of Biology, Chemistry, Physics, and General Science.*—Of the teachers who reported this item, those who were teaching physics were, on the whole, less well trained in subject matter than those who were teaching either biology or chemistry, since 50.5 per cent of the men and 61.1 per cent of the women teachers of physics reported fewer than eleven undergraduate hours of subject matter, while 22.2 per cent of the men and 13.5 per cent of the women teachers of biology, and 12.2 per cent of the men and 19.3 per cent of the women teachers of chemistry reported fewer than 11 undergraduate hours of subject matter. Also a larger percentage of men and women teachers of biology and chemistry than of physics had had more than 20 hours of undergraduate and of graduate hours of subject matter. On the whole, the women teachers of biology had had more undergraduate hours of subject-matter preparation than the men; the opposite was true with respect to the men and women teachers of chemistry and physics.

Most of these men and women teachers of general science had had more or less subject-matter training in four or more branches of science; the modal number for the men was five and for the women, four. It must be remembered, however, that closely allied courses such, for example, as hygiene, sanitation and bacteriology, were listed by many teachers as separate branches of science and could not be considered otherwise in preparing these tabulations. Moreover, the subject-matter training of a considerable percentage of these teachers was inadequate, since it was too highly specialized and was not sufficiently well distributed among the branches of science

included in the course material of general science. On the whole, the men teachers of this subject had a somewhat more widely differentiated training in the subject matter of science than the women.

11. *Teaching Load of Teachers of Science.*—Nearly three-fourths of these teachers had schedules which included between 20 and 30 periods of teaching per week. There are no significant differences in the number of periods taught per week by teachers of the four major subjects.

12. *Teaching Combinations.*—Each branch of science was found in teaching combination with almost every other subject. Apparently no subject in the entire program of studies of the high school was too far removed from science to be combined more or less frequently with it. In general, but only to a somewhat limited extent, this condition was found to improve with the size of the school.

13. *Periods per Week Devoted to Science.*—Although there was considerable variation in the number of periods per week provided for the four major branches of science, either five or seven periods per week were used in the majority of schools represented by the teachers' programs. Chemistry and physics were offered seven periods per week in, respectively, 57.0 and 58.9 per cent of the schools, while these same subjects were offered five times per week in, respectively, 36.9 and 34.9 per cent of the schools. This situation is reversed in the cases of biology and general science, for which there was a provision for five periods per week in, respectively, 49.4 and 74.0 per cent of the schools, and for seven periods per week in, respectively, 45.3 and 21.5 per cent. These four subjects were offered fewer than five times per week each in less than 1.0 per cent of the schools; and biology, physics, and chemistry were offered 10 times per week in, respectively, 2.9, 4.2, and 3.1 per cent of the schools.

The modal number of different subject preparations per teacher per day was two. More than 25 per cent, however, of

the teachers in schools enrolling between one and 251 pupils, had five or more different preparations per day. In general the number of different preparations per day bore an inverse relation to the size of the school.

14. *Number of Periods Devoted to Laboratory Work.*—The administrative plan most frequently reported for the four major branches of science provided two double laboratory periods per week; the percentages of teachers reporting this plan were 46.6 (biology); 58.8 (chemistry); 58.6 (physics); and 22.3 (general science). No definite periods were scheduled for laboratory work in 71.8 per cent of the programs of teachers of general science, in 38.8 per cent of those of teachers in biology, in 22.1 per cent of those of the teachers of physics, and in 21.8 per cent of the programs of teachers of chemistry. This statement should doubtless be interpreted to mean that in these programs such laboratory work as was included was given whenever it best fitted with the development of the work.

15. *Size of Science Classes.*—The modal class in biology and in general science had an enrollment of between 26 and 30 pupils; that in chemistry and physics had an enrollment of between 21 and 25 pupils. More than one quarter (26.6 per cent) of these classes in general science, and about one-sixth (16.8 per cent) of the biology classes had between 31 and 40 pupils enrolled.

In general, as would be expected, the size of class tended to increase with the size of the school, not only in the major, but also in the minor branches of science.

16. *The Individual or the Demonstration Plan of Laboratory Work.*—With biology and general science the modal number of teachers used a combination of individual pupil experimentation with teacher and pupil demonstration; with chemistry and physics a majority of the teachers used individual pupil experimentation exclusively. With biology, individual laboratory experimentation by pupils was used exclusively by almost

as many teachers as used the combination plan of individual experimentation and demonstration. While individual pupil experimentation was used exclusively by relatively few (8.1 per cent) of the teachers of general science, 42.2 per cent used the individual plan more or less frequently, while 85.7 per cent of these teachers used some form or other of the demonstration plan. Some teachers of each of the branches of science gave courses without any laboratory work whatever; the smallest percentage was found among teachers of physics (1.1); the largest among teachers of general science (5.9). Exclusive teacher demonstration was used by a relatively small percentage of teachers, except those of general science.

17. *Even-front and Rotation Plans of Laboratory Work.*—The "even-front" plan was used by a large majority of the teachers of biology, chemistry, and general science; the rotation plan was used by a large majority of the teachers of physics.

18. *Proportionate Use of Single Textbook and Syllabus.*—Respectively 82.6, 89.7, 88.9, and 92.5 per cent of the teachers of biology, chemistry, general science, and physics followed either a single textbook, or a syllabus based on a single textbook, with supplementary references. It would seem from the data that there is more latitude with biology than with the other three subjects, since more than half the teachers of that subject used a syllabus of some sort, and another 14.8 per cent used a syllabus based upon no particular textbook.

19. *Use of Supplementary Periodical Literature.*—Of the teachers of the four major branches—biology, chemistry, general science, and physics, respectively 84.6, 87.0, 71.5 and 87.4 reported occasional but regular classroom use of periodicals such as *Popular Science*, *Current Science*, *The Science Classroom*, etc.

20. *Extracurricular Duties of Teachers of Science.*—Most of these teachers of science assumed responsibility for one extracurricular activity; only 8.5 per cent of the men and 7.2 per cent of the women sponsored more than two such activities.

21. *Professional Reading of Teachers of Science.*—The occasional reading of professional literature was far more frequently reported than its regular reading. The educational publications most frequently listed both for regular and for occasional reading were *School Science and Mathematics*, *Science Education*, *Journal of Chemical Education*, and *The School Review*. Of the scientific journals, those most frequently listed were *Science News Letter*, *Popular Science Monthly*, *Scientific American*, *Science*, *Science and Invention*, *Chemistry Leaflet*, *Scientific Monthly*, and *The Science Classroom*.

STUDY NO. 207

Science Education in the Secondary Schools of Sweden[1]

By Holger Frederick Kilander*

Problem.—To determine the educational practices with respect to the teaching of biology, physics, chemistry, and hygiene in the secondary schools of Sweden.

Method.—During the summer and fall of 1928, the investigator visited secondary schools in Sweden, attending and observing classes in the various branches of science. "Conferences and discussions were held with numerous science teachers, authors of science textbooks, members of the Royal Board of Education, and other educators. Facilities for science instruction, such as rooms, equipment, and apparatus, were investigated. . . . An extensive study of the literature on

[1] Compare this study and the following one by Efron with that of Meier, *Investigations in the Teaching of Science*, Vol. II, pp. 62–64.

* Dissertation for the degree of Doctor of Philosophy, Contributions to Education, No. 463. New York: Bureau of Publications, Teachers College, Columbia University, 1931. Only the portions of this extensive investigation which deal directly with the teaching of science are here briefly digested. A report of this study appears under the title, "Science Education in Sweden," in *School Science and Mathematics*, XXXII (May, 1932), 522–530.

science education and education in general was undertaken. This included books dealing with Swedish education and education in general, courses of study and textbooks, educational periodicals, statistics and laws, and reports including published and unpublished material issued by the Royal Board of Education, examination questions and papers, notebooks, and other written work."

Findings and Conclusions.—1. "In the eight years of the Swedish secondary school (the fifth to and including the twelfth year of schooling) much more science is taught than in the United States. Even in the classical line it is in excess of that found in the United States. This applies to all sciences though least to chemistry."

2. Science education begins in the Swedish elementary schools, with children of the average age of 10 years, who study to some extent each of the three major sciences. This study is continued in the *real* school (intermediate school) and in the *Gymnasium*.

3. "Each science, as a rule, is taught yearly so that a student is studying all three sciences simultaneously. This method permits a better division of the content by age levels."

4. "There is a definite sequence in the science training. This eliminates overlapping of content in the three sciences and in successive years of a given science. A sequence is possible because all students take the same program except in the last two years of the *Gymnasium*. Each science is planned to assist the following year's course in some other science whenever possible."

5. "Laboratory work is very limited. The 'Reform of 1927' increased the amount and made it compulsory. The crowded curriculum does not permit it to be taught to the extent found in American schools. Demonstration experiments are very numerous, and offset the lack of the individual laboratory work." Individual laboratory work is introduced to provide self activity.

6. "In the lower grades the stress is placed upon the practical content and applications, whereas in the higher grades, such as in the *Gymnasium*, the stress is largely upon the theoretical and mathematical."

7. "The instruction centers about the teacher and the class demonstration." Textbooks are "factual, condensed, well illustrated, and limited to essentials"; they are used mainly "to supplement the other work." "The students are compelled to think and grow with the subject. The emphasis is at the same time upon memory work."

8. "The content of most subjects, including the sciences, contains much that is a survival of the past and that could very well be eliminated. This situation exists beside an already overcrowded curriculum."

9. "The trend in science instruction is toward more individual laboratory work and an elimination of non-essentials; from the morphological to the physiological in biology; from the mathematical to the more practical in physics; in general, toward making the science training more like that in the United States, though retaining its own desirable features."

10. "Sweden is the only country which requires the Doctor's degree for the position of master in the state secondary schools." "A brief course in pedagogy is the only professional education received at the university. The training of teachers in the secondary schools is entirely academic, very extensive in science subject matter, and compares with that of the average college teacher."

11. The most frequent combinations of subjects for the required practice year and for the additional two years of teaching prerequisite for permanent appointment, are, for science teachers, mathematics and physics, physics and chemistry, biology and chemistry, and biology and geography.

12. "Teachers of the private secondary schools for girls are either university trained or receive their training in a teachers college which builds upon 11 years of studies. The train-

ing in science in this college is approximately equal to three years of high-school biology, two years of physics, and one year of chemistry."

13. "The state normal schools for elementary-school teachers give a science training not quite equal to that of the *Gymnasium*," but "in terms of American high schools it is approximately equal to two years of biology, two years of physics, and one and a half years of chemistry."

14. "A new feature in the science training of the normal school is the combination of physics with sloyd. It is being introduced into the elementary schools and some of the intermediate schools."

15. "Few examinations are given except at the end of the last year of a school form. These latter exercise a marked influence on the character of the school work."

STUDY NO. 208

The Teaching of Physical Sciences in the Secondary Schools of the United States, France, and Soviet Russia[1]

By Alexander Efron*

Problem.—(1) To discover "the salient characteristics of the teaching of physical science in the secondary schools of the United States, France, and Soviet Russia"; (2) to evaluate and compare "the types of teaching procedures observed"; and (3) to determine "the possible implications of foreign practice" for the teaching of physical science in the United States.

[1] Compare this study and the preceding one by Kilander with that of Meier, *Investigations in the Teaching of Science*, Vol. II, pp. 62–64.

* Dissertation for the degree of Doctor of Philosophy, Contributions to Education, No. 725. New York: Teachers College, Columbia University, 1937. A report of this study appears under the title, "Science Teaching in France and Soviet Russia," in *Science Education*, XXII (March, 1938), 121–123.

Method.—The investigator made as close a comparison as possible of the three countries with respect to the following aspects: Secondary education and the role assigned in it to physical science; present programs and curricular trends in physics and chemistry; time allotments, organizations of materials, tests and examinations in these subjects; the training of teachers of physics and chemistry; methods of teaching these subjects; the nature and place of the textbooks of physics and chemistry; apparatus, supplies, equipment and facilities for teaching the physical sciences; enrichment through extracurricular work (in the United States and Russia); and other aspects of science instruction.

The data for making these comparisons were obtained for France and Russia in 1935, during the investigator's seven-months' resident study in these countries. The study included (1) "observation of actual full-period physics and chemistry lessons (36 in France and 21 in U.S.S.R.); (2) inspection of foreign schools, particularly of their demonstration and laboratory equipment; (3) "visits to teacher-training centers . . . ; (4) conferences with officials and representatives of school systems . . . ; (5) conferences with principals, teachers, and subject-matter specialists; (6) visits to centers for the improvement and design of apparatus . . . ; and (7) visits to centers of extracurricular science activity in the Soviet Union, as well as attendance at meetings of several pedagogic associations in France. In addition, a detailed study was undertaken of the official programs, time schedules, courses of study, government laws and decrees pertaining to education, typical textbooks, supplementary reading materials, visual aids, tests and examinations, etc."

The data for the United States were obtained from the investigator's 15 years' experience as a teacher of physics and as chairman of a department of physical science in New York City high schools, "supplemented by a series of visits to science classes in neighboring cities, conferences with science

specialists and supervisors, investigations of apparatus-building and science-exhibit centers, study of typical state science programs, and examination procedures, etc."

Conclusions and Implications.—1. The American secondary school is superior to those of France and Russia "in the broadness of its democratic program, as evidenced by the high proportion of the adolescent population enrolled, the richness and variety of the curricular and extracurricular offerings, and the adaptation to the needs of a heterogeneous unselective clientele. Unlike the European secondary school, however, the American high school lacks historical perspective, is unhampered by external standards, and exhibits no clear-cut educational philosophy. It has not yet evolved a definite purpose and such a truly national objective as the French *culture générale*, or the Soviet idea of *polytechnization*. It retains, instead, an empirical, pragmatic, 'progressive' point of view which offers sharp contrast to the logically formal approach of the French *enseignement secondaire* or the dialectical procedure of the Russians."

2. "American science teaching, too, is confused in both scope and ultimate purpose. Present-day psychology and the newer theories of educational transfer render impossible the acceptance of the French belief in the efficacy of science education as an instrument of culture and a factor in mental training. Likewise, the Soviet point of view that science is a weapon for the reconstruction of the social order is at variance with our own tendency to regard the study of secondary-school science as an adventure in liberal education . . . A possible solution of the problem of orientation of both secondary education and the teaching of physical sciences, consonant with the democratic traditions of the American school, may be sought in the foreign practice of organizing differentiated and specialized post-primary schools, each dedicated to a certain specific task and hence possessed of a definite educational point of view. While no general acceptance of this principle

can as yet be reported, a movement in this direction has begun as the result of the adoption of national and state vocational-school programs and the inauguration of such school types as the scientific, technical, classical, arts and crafts, and others."

3. "No conclusion, valid as a guide for American practice, can be drawn from the comparative study of science programs and time schedules. The rigid selection practiced in France and the ideological-political viewpoint governing education in Soviet Russia preclude the possibility of adoption of similar science programs with our unselected groups for whom physical sciences remain one-year, unrelated, and unintegrated electives. The concentric or spiral arrangement of the material of physics in use in the secondary schools of both France and Soviet Russia has, on the other hand, much to commend it in any setting where the intellectual maturity of the learner is an important factor. The quantitative point of view of French physics and the technological bias imparted to Soviet chemistry appear to be unacceptable in the American program of general, unspecialized science education."

4. "The training of science teachers in the United States has recently made great progress through an inclusion of liberal education, professional preparation, and systematic in-training and supervision. The French emphasis on pure scholarship is undoubtedly productive of a true teaching *élite* equal in subject-matter preparation to our Ph.D.'s in science"; on the other hand the very brief professional preparation of teachers "renders French teaching too expository and analytical in character. Soviet Russia's new program of teacher training, combining as it does both subject-matter and pedagogic preparation, has much to commend it to the American observer; the Russians, however, still face the problem of 'liquidating' the shortcomings of thousands of their secondary-school science teachers who are not yet university graduates and are thus inferior to the best science teachers in the United States."

5. "American methods of teaching science on the secondary-school level are, on the whole, more original, varied, and skillful than those in vogue in the other two countries under investigation. The techniques of demonstration and laboratory work, the individualization of classroom procedure, the use of the blackboard and other visual devices, the systematic testing of the results of instruction, and the various methods of supervised study, project work, enriched teaching, etc., are such as to insure, in the hands of the best American science teachers, a measure of pupil participation not readily found in the classrooms of other countries. Much can be learned, however, from the French emphasis on clarity of exposition and care in oral and written expression. The Soviet program of testing laboratory accomplishments and the Soviet motivation technique, which draws its strength from the technical and industrial life which surrounds and permeates the school at every point, form an innovation in science teaching that is deserving of further study."

6. "France has little of value to offer us" with respect to extracurricular activities, "her energy being almost completely devoted to the rigorous classroom program of the *lycée* and the higher primary school. Soviet Russia, on the other hand, has so related her extracurricular science program to the Plan of National Economy as to make it possible for after-school science clubs, children's technical stations, and inventors' circles to function integrally with the associated shops, factories, power plants, and collective farms. The result is that the Soviet science pupil participates in a science program that derives its significance from the totality of his everyday experiences."

STUDY NO. 209

Science for the Consumer[1]

By W. A. Partridge* and Henry Harap

Problem.—(1) "To discover the scientific terms occurring in publications of Consumers' Research Incorporated"; and (2) "to classify these terms for the benefit of persons interested in the development of science for consumers."

Method.—An analysis of the publications of Consumers' Research Incorporated was made to discover such scientific terms as "might reasonably be included in the subject matter of the several sciences," and as were "of such common usage that any forward-looking teacher of science would want to consider them for inclusion in a course of study." "Each term was placed on a card together with the commodity name under which it occurred." This procedure yielded 718 cards which were subsequently reduced to 349 by eliminating duplication.

The data were classified in several ways: "The first was a classification of terms as they occurred by commodities. The cards were sorted under commodity headings, alphabetized, and then recorded. The second was a classification of terms arranged alphabetically, followed by the names of the commodities in connection with which they were used. The third was the arrangement of the terms and commodity listings under the various school subjects. The cards were sorted according to school subject and division of the subject, then alphabetized and recorded."

Findings.—Table LXXXIX shows the statistical summary of the analysis.

[1] See also study by Harap, *Investigations in the Teaching of Science*, Vol. II, pp. 332–334.

* *School Science and Mathematics*, XXXIII (March, 1933), 266–274.

TABLE LXXXIX

SUMMARY OF OCCURRENCE OF SCIENTIFIC TERMS IN BULLETINS FOR CONSUMERS

Topic	Number of scientific terms found	Number of commodities in which terms are used
Biology	52	78
Animal	3	4
Human	39	60
Plant	10	14
Chemistry	85	203
Acids and bases	18	60
Carbon compounds	7	18
Sodium compounds	13	35
Sulphur compounds	2	6
Metallic earths	10	16
Metals	15	30
Organic chemistry	20	38
Health and hygiene	70	118
Drugs and medicine	40	68
Diseases and treatment	24	35
First aid	6	15
Home economics	44	88
Foods	33	71
Textiles	11	17
Physics	95	177
Electricity	12	18
Heat	12	42
Light	16	22
Mechanics of solids	12	18
Mechanics of fluids	10	18
Mechanics of gases	24	44
Sound	5	7
Electro chemistry	4	8
Unclassified	5	

The list of scientific terms and commodities follows:

SCIENTIFIC TERMS IN CONSUMER BULLETINS AND THE COMMODITIES TO WHICH THEY ARE RELATED

Abrasive: furniture polish, knife sharpener, laundry soap, metal cleaner, rubber tile, scouring powder, soap powder
Absorption: sanitary napkins, silk
A.C. Current: household appliances, radio
Acetic acid: acids, antiseptics, bleaching agents
Acid: concrete, enamelware, food, ink, linoleum, motor oil, pressure cooker, rubber tile, silk
Acid-alkaline balance: drugs
Acidosis: drugs
Acoustics: radio sets
Adulteration: canned goods, catsup, cereal, fruit juices, jellies, olive-oil, preserves, silk
Aerodynamics: automobiles
Alimentary tract: baking powder, yeast
Alkali: coffee, laundry soap, toilet soap, water softener
Alkali carbonate: cocoa, chocolate
Alkali metal salt: fire extinguishers
Alkaline: food, ink, linoleum, metal cleaner, paint, soap powder, water softener, aluminum ware
Alkaline antiseptic: drugs
Alloy: acids, aluminum ware, enamelware, pewter, silverware
Aluminum salts: baking powder, fire extinguishers, paint
Amalgam: dental filling
Ammonia: brushes, fertilizer, floor wax, refrigerator
Ammonium hydroxide: caustics
Amplification: radio
Analine dye: blueing; hair dye, woolen
Anhydrous sodium bicarbonate: boiler compounds
Anti-acid effect: mineral water
Antimony: enamelware, furniture polish
Anti-rachitic vitamin: foods, fruit
Anti-scorbutic vitamin: food, milk
Antiseptic: bleaching agent, disinfectant, hair tonic
Anti-sterility vitamin: cereals, food
Arsenic: fruit, insecticide, hair dye, sugar
Asbestos: fireproofing, insulation
Aspirin: drugs
Asphyxiation: furnace, gas stove, refrigerator, water heater
Atmospheric pressure: hot air furnaces
Audio frequency: radio
Automatic shock absorbers: automobile
Automatic switch: coffee machine, electric iron, toaster
Automatic volume control: radio
Bacteria: acidophilus, disinfectants, milk, refrigerator
Bacteriacidal power: ultra violet light, disinfectants, mouth wash
Bacterial toxin: frozen foods
Base: cosmetics
Basic fat: toilet soaps
Battery: radio, automobile
Bearings: vacuum cleaners
Belladonna: drugs
Benzoic acid: deodorants

Biologically standardized: cod liver oil, foods
Bleaching agents: cosmetics, disinfectants
Brake horsepower: automobiles
Bromate salts: cereals, drugs
B.T.U.: coal, gas, furnaces, household appliances, oil, stoves, radiators, refrigerators, steam boiler, water heaters
Builder: laundry soaps, soap powders
Caffein: coffee, soft drinks, drugs
Calandered: cotton
Calcification: cereals
Calcium chloride: coke, fire extinguishers
Calcium hypochlorite: bleaching agents, disinfectants
Calcium oxalate: fruits, vegetables
Calcium salts: cereals, water softeners
Calorie: foods, reducing preparations
Calyx parts: fruits
Cancer: laxatives, radium nostrums
Carbohydrates: canned foods, cereals, foods, sugar
Carbon dioxide: fire extinguishers, soft drinks
Carbonization: coke
Carbon monoxide: air conditioning unit, automobiles, cook stoves, gas heaters, water heaters
Carbon tetrachloride: cleaning agents, cotton, dry cleaning, fire extinguishers
Carotene: foods
Carrier waves: radio
Catalysis: fire extinguisher
Caustic potash: caustics, cuticle remover
Cellulose: cereals, disinfectants, sanitary napkins
Cellulose acetate: rayon, textiles
Chemical analysis: foods, drugs
Chemical warning agent: refrigerator
Chemical wash: fruits, rugs
Chlorine: bleaching agents, coke, fire extinguisher, rugs
Chloroform: cleaning agents
Chrome tanned: shoes
Chromium plate: electric iron
Citric acid: gelatin, soft drinks
Clinic: disinfectant
Cold storage: eggs, fruits
Combustion: coal, oil
Commutator: vacuum cleaners
Compression ratio: automobiles, gasoline
Compressor: refrigerators
Convection currents: gas heater, humidifier, hot air furnaces, refrigerator
Corrosion: automobile, enamelware, hot air systems, household oil, ink, pipe, refrigerators, stainless steel, table grills
Crystalline substance: disinfectants, honey
Cubic centimeter: ink
Cultured milk: dairy products
Cupra ammonium process: rayon, textile
Decomposition: canned foods, catsup, frozen foods
Deficiency diseases: foods, cereals
Density: maple syrup, oil
Deodorant: refrigeration, cosmetics, disinfectants

Dermatosis: drugs
Desensitization: milk
Detector: radio
Dextrose: sugar
Diffused light: lighting systems
Disinfecting agent: sweeping compounds, toilet soaps
Distillation: coal, water
Down-draft carburetor: automobiles
Drying oil: cleaning agents, paint
Dynanic speaker: radio
Electric shock: mechanical exerciser (see shock hazard)
Electrolitic action: aluminum ware, metal cleaner, pipe
Electromagnetic switch: automobiles
Electroplating: metal cleaner, silverware
Electrolyte: ink, radio battery
Element: electric iron, radiant heater
Emulsion: milk, rubber tile, plaster
Essential elements: food
Essential oil: cosmetics, tooth paste, soft drinks
Ethane: gas stoves
Ether: anesthetic, cleaning agent
Ethyl bromide: refrigerators
Ethyl chloride: refrigerators
Exchange silicate process: water softeners
Feldspar: abrasives
Fermentation: honey, tea
Ferric chloride: drugs
Filament: electric light, radio, radio tube
Filter paper: coffee machines
Focal length: camera
Focus: camera
Food calcium: foods
Food constituent: cereals
Food phosphorus: foods
Foot candle: lighting system
Formalin: cereal, deodorant, drugs, hair tonic
Formula: cereals, drugs
Free wheeling: automobiles
Frequency controlled: clocks
Fuller's earth: abrasives
Fumigant: drugs, exterminators
Functional disability: drugs
Fungus: drugs
Galvanize: iron work, lath
Gastric juice: disinfectant, baking powder
Gastro-intestinal infection: cereals, foods
Germicidal agent: laundry soap, soap powder, drugs
Glandular extract: drugs
Glaze: enamelware
Glucose: sugar
Goiter: food, salt
Gram: ink, silverware
Gravity: hot air furnaces, hot water system, lubricating oils
Heat conductivity: shoes
Hemoglobin: ultra-violet ray apparatus
Horological institute: clocks
Horsepower: automobiles
Hydraulic brakes: automobiles
Hydraulic shock absorbers: automobiles
Hydrocarbon: gas stoves, laxatives
Hydrochloric acid: acids, cleaning agents, deodorants, enamelware, fire extinguisher
Hydrocyanic acid: exterminators. insecticide

Hydrogen peroxide: bleaching agent, disinfectant
Hydrometer: battery, oil
Humidity: air-conditioning unit, films, furnaces, radiators
Humus: fertilizers
Ignition: automobiles, oil burners
Impermeability: rubber tile
Inactivation: food
Infra-red ray: ultra-violet light
Infection: drugs
Infusion: tea
Infusorial earth: abrasives
Inorganic matter: gelatine, laundry soap, soap powder
Insoluble: water softener
Insulation: boiler, coffee maker machine, cook stove, food mixer, furnace, household appliances, oil burners, pipe, refrigerator, roofing, table grill, water heater
Insulin: drugs
Intestinal putrefaction: milk
Iodine: food, salt
Irradiation: cereal, ergosterol, food, ultra-violet light appliances
Isobutane: gas stove
Javelle water: bleaching agents
Kilowatt-hour: electric stoves, household appliances: refrigerators
Lactic acid bacillus: milk
Lanolin: cosmetics
Larvae: insecticide
Lead acetate: metal polish
Lead poisoning: pewter, paint gasoline
Legume: food
Linear magnification: field glasses
Lubrication: automobiles, vacuum cleaners
Magnesium: magnesite, pipe, water softener
Magnetic pickup: radio
Mercerized: cotton
Mercury salts: cosmetics
Metallic dye: hair dye
Metallurgist: pewter, silverware
Methyl bromide: refrigerators
Methyl chloride: refrigerators
Micro-organism: mouth wash
Microscope: dinnerware, silk
Mille-microns: food
Mineral matter: silk
Mineral salt: canned food, cereal, food
Mineral wool: insulation materials
Mixed diet: food
Mucin film: tooth-paste
Mucin plaque: tooth paste
Mucus membrane: disinfectant
Muntz metal: pipes
Neutral salt: food
Neutral soap: blankets, drugs, silk
Nitro-benzene: furniture polish
Nitro-cellulose: rayon
Non-corrosive: disinfectant
Oak tanned: shoes
Octane rating: gasoline
Opaque: enamelware
Opiates: radium nostrums
Oral antiseptic: tooth paste
Oral mucus membrane: tooth paste
Organisms: meat
Orthodichlorobenzene: cleaning agents, metal polish
Orthopedics: hearing aid
Oxalic acid: acids, bleaching agents, fruits, metal polish, vegetable
Oxidation: metal cleaner, insulating materials

Ozone: ultra-violet light, ventilating devices
Pasteurize: food, milk
Pathogenic-disability: foods
Pathogenic-organism: disinfectant, yeast
Pellagra: food
Perspiration: silk
Petrol-cracking: gasoline
Phenol coefficient: disinfectants
Phosphoric acid: jelly, preserves, fertilizers, metal cleaner
Phosphorous assimilate: viosterol
Potash: fertilizer
Potassium bromide: cereals
Potassium chlorate: tooth pastes
Potassium permanganate: drugs
Precipitate calcium phosphate: tooth pastes
Preservatives: cereals, foods, fruit juice, meat, syrup, soft drinks
Pressure gauge: pressure cookers, boilers
Prism binocular: field glasses
Prophylaxis: viosterol
Proprietary repellant: exterminator, insecticide
Radiation: oil burners, radiator, steam heating systems
Radio-activity: nostrums
Radio frequency: radio sets
Refrigerant: air conditioning, refrigerators
Relative humidity: air conditioning, cool, humidifiers
Resilience: rubber tile
Resorcin: hair tonic
Rickets: viosterol
Rottenstone: abrasive
R. P. M.: automobiles
Saccharine: mouth wash, soft drink
Safety fuse: coffee machine
Safety valve: pressure cooker, steam boiler
Salicylic acid: drugs
Sanfordizing: shirts
Scanning disc: television
Screen grid: radio sets
Selective sliding-gear: automobiles
Selectivity: radio sets
Sensitivity: radio sets
Shatter-proof glass: automobiles
Shock hazard: electric grill, electric toaster, food mixer, vacuum cleaner, waffle iron, water heaters
Short wave: radio sets
Silichrome steel: gasoline
Silver sulphide: metal cleaner
Skin glands: cosmetics
Slaked lime: whitewash
Snubbing action: automobiles
Soda-lime process: water softener
Sodium bicarbonate: deodorant, drugs, fire extinguisher, mouth wash, tooth paste
Sodium-carbonate: bath salts, bleaching agent, caustics, cosmetics, metal cleaner, scouring powder, sodas, water softener
Sodium citrate: soda
Sodium fluoride: insecticide
Sodium hydroxide: caustics, disinfectant, water softener
Sodium malate: salt
Sodium perborate (borax): bath salts, water softener
Sodium sesqui-carbonate: sodas, metal cleaner
Sodium silicate: boiler compound, eggs, soda, toilet soap

Sodium thiosulphate: metal cleaners
Solarization: ultra-violet light appliances
Solubility: disinfectant, laundry soap, silk
Solvent: cleaning fluids, furniture polish, laundry soap, metal cleaner, soap powder
Spontaneous combustion: cleaning agent, coal, floor oil, floor wax
Stainless steel: knives, knife sharpeners, metalware
Stereoscopic photography: camera
Sterilization: mouth wash
Streamlining: automobiles
Strychnine: drugs
Suction: vacuum cleaner
Sugar of lead: drugs
Sulphate: baking powder, coal
Sulphur dioxide: canned foods, cereals, dried fruits, refrigerators
Superheterodyne: radio sets
Synthetic fiber: rayon, silk
Synthetic oil: bath salts, soft drinks
Tannic acid: drugs, ink, tea
Temperature compensation: automobiles
Tensile strength: cotton, silk, insulation
Tetraethyl lead: cleaning agent
Thermal equivalent: refrigerator
Thermostat: automobile, dampers, electric iron, electric radiators, furnace blowers, electric coffee-making machine, gas furnace, gas stove, heating pad, mechanical stoker, oil burner, heating system, waffle iron, water heater
Thyroid extract: reducing preparation
Thyroid gland: foods
Thyroxin: drugs
Tincture of iodine: disinfectant
Titanium zinc: paint
Tone control: radio sets
Tone quality: piano, radio sets
Toxic action: baking powder, can opener, dry-cleaning machine, gasoline, milk
Toxic solvent: cleaning agents
Transformer: radio sets
Translucent: dinnerware, lighting
Transmission: automobiles
Trench mouth: mouth wash, tooth paste
Trisodium phosphate: bath salts, boiler compounds, laundry soap, scouring powder, soap powder, soda, metal cleaner, water softener
Ulceration: depilatories, cereal
Ultramarine blue: analine dye
Ultra-violet ray: apparatus, hair tonic, drugs, food, glass
Unbleached: cereal
Vaccine: drugs
Vacuum: carpet sweeper, coffee, coffee grinder, vacuum bottle, vapor heater
Vacuum clutch control: automobile
Vacuum tube: radio
Viosterol: cod liver oil
Viscose: rayon
Viscosity: automobiles, cleaning agents, furniture polish, household oil, lubricating oil
Vitamin A: fruits, vegetable, yeast
Vitamin B: cereal, cod liver oil, laxatives, reducing preparations
Vitamin C: cereal, food, fruits, fruit syrup, vegetable

Vitamin D: cereals, fruit, fruit syrup, foods, milk, pickles, pressure cookers, tea
Vitamin E: cereal, cod liver oil, food precursor, viosterol, yeast
Vitamin F: cereal
Vitamin G: cereal
Vitamin potency: butter substitute, eggs, food, milk
Vitreous porcelain: dinnerware, refrigerator
Volatile: gasoline, coal
Water softener: soap powder
Watt: electric light, electric iron, machines (ironing)
Wave length: food
Weighting: silk, sheets, silk dresses, cotton
Whiting: abrasive
X-ray: depilatory, drugs
Zinc oxide: cosmetics, paint
Zinc stearate: cosmetics

STUDY NO. 210

A Study of Allusions to Science in Magazines

By Eveus Newland*

Problem.—To determine the understanding necessary for reading allusions to science in current magazines.

Method.—An analysis was made of 201 issues of four types of popular magazines: (Literary Magazines) *Atlantic Monthly, Harpers Magazine, Literary Digest;* (Home Magazines) *Good Housekeeping, Ladies' Home Journal, Woman's Home Companion;* (Story Magazines) *Saturday Evening Post, Collier's Weekly, American Magazine;* and (Children's Magazines) *St. Nicholas,* and *Child Life.* These issues "were as evenly distributed as possible over the 10-year period" from 1921 to 1930. "Every page of each issue was analyzed for science allusions, the advertisements as well as the stories and the articles, or content." A total of 2,490 different allusions to science were thus secured and these, with their 24,022 attendant meanings or contexts were recorded, grouped, and tabulated.

Findings and Conclusions.—1. "A very small number of allusions are mentioned with great frequency, while a great number of allusions are mentioned but once. Only 2 per cent of the allusions occur 100 times and over, while 41 per cent

* *Science Education,* XXI (October, 1937), 126–130.

Table LXXXX

THE TEN ALLUSIONS TO SCIENCE MOST FREQUENTLY FOUND IN 201 ISSUES OF MAGAZINES, WITH THE FREQUENCY OF OCCURRENCE AND NUMBER OF MEANINGS OF EACH ALLUSION IN THESE ISSUES

Allusion contexts	Frequency of occurrence			Number of meanings	
	In context	In advertisements	In both	In context	In advertisements
*Electricity	443	109	552	64	22
Wiring for home	34				
Reference to home equipment		24			
Refrigeration, methods of	21				
Radio	282	193	475	45	8
Description of, reference to home use		148			
As a factor in commercial aviation	29				
Description of, reference to power		24			
Acid	59	370	429	17	6
Control of, reference to tooth paste		316			
As an element in fruit	9				
Test for, reference to litmus paper	5				
Teeth	32	369	401	2	10
Care of, reference to patent preparations		151			
As factors having direct influence on health		29			
Care of, in connection with health program	26				
Hair	49	311	360	4	1
Care of, reference to patent shampoo and tonic		311			
Care of	22				
Function and characteristics of	20				
Science	329	6	335	26	2
As means of controlling living conditions	76				
Principles of, discussed in religion controversy	66				
Principles of, reference to tooth film		3			
Vitamin	67	254	321	18	15
As a factor in cereals		59			
Source of, reference to cod-liver oil		28			
As a health requisite	10				
Germ	28	283	311	9	23
Control of, reference to tooth paste		110			
Control of, by household disinfectants		30			
As organism carried by insect	6				
Skin	50	245	295	18	15
Care of, reference to patent preparations		119			
Disorders of, as condition cleared by yeast		32			
Care of	26				
Lamp	41	237	278	10	3
Description of, as electric household appliance		206			
Value of, reference to ultra-violet ray		12			
Function of, in explanation of television	5				

* Table LXXXX is read thus: The allusion, *electricity*, ranked first, occurred 443 times in the context, 109 times in the advertisements and had a total frequency of 552. It had 64 different meanings in the context and 22 meanings in the advertisements.

. . . occur three times or less." ". . . probably . . . very few of the allusions occur frequently enough to justify their emphasis in a teaching program."

2. Only 50, or 2 per cent, of the allusions are persistent over the 10-year period; however, those most frequently mentioned are also the most persistent ones.

3. ". . . the number of contexts associated with the allusions in the content of the magazines ranges from 64 to 1"; only 39 per cent of the allusions have more than one meaning each. ". . . the allusions having the greatest number of contexts are among the most frequent allusions."

4. "In general, the most important contexts of the important allusions to science are concerned with personal health, food elements in relation to health, and household appliances."

5. ". . . the contexts of allusions in the content of the magazines contribute more evidence of change in meaning over the 10-year period than do contexts of allusions occurring in advertisements of the magazines."

6. ". . . of the four types of magazines, the literary type ranks first in frequency of occurrence of allusions, followed in order by the home, the story, and the child types."

Table LXXXX shows the 10 most frequently occurring allusions with the three most common contexts or meanings of each allusions.

STUDY NO. 211

Science Interests of Junior-high-school Pupils

By Charles H. Nettels*

Problem.—To study the interests of pupils in various topics of general science in order to determine (1) what topics appeal most strongly to the interests of boys and of girls, and (2)

* *Science Education*, XV (May, 1931), 219–225.

whether there are marked differences in the interests of dull, average, and bright pupils.[1]

Method.—The following questionnaires were submitted to pupils in one of the junior high schools of Los Angeles:

To pupils of the A-7th Grade:

You will be entering a science class next semester. There you will have an opportunity to have many questions answered that have been puzzling you. Science teaches us about the sky and the earth. It tells just what things are used to manufacture many things people need. Science explains how everything grows and how to build up and take care of our bodies. In science, we study how goods, people, and messages are carried on land, sea, and in the air. It also tells how our homes and lives are made more comfortable. Science teachers are anxious to tell children about all of these wonders. They want to tell you about things that interest you. Will you write down five different things in science that you would like to learn? Write one after each number below.

To Pupils of the A-8th Grade:

You have by this time had some experience with the study of science. You know that it helps you to understand the things that you never understood before. Perhaps many things you wanted to know were explained and others were not. Next year you may choose general science and learn more of the wonders of this subject. To enable you better to understand the things in science, the teachers are asking you for a list of science topics that you are interested in. Will you think over carefully the various things science tells about and write down the five you think most interesting, after the numbers listed below?

To Students of A-9 General Science:

You have by this time advanced far enough in the study of science to know many of its fields, and have no doubt formed an opinion of which kind you like best. In order that the teachers of science may be most helpful to you, they desire to know what boys and girls of your age find

[1] See also studies of interests by Trafton, Mau, Downing, Washburne, Finley, Pollock, and Curtis, *Investigations in the Teaching of Science*, Vol. I, pp. 119–123, 123–128, 129–131, 153–155, 155–159, 204–207, 265–267, and 326–333, respectively; by Palmer, Craig, and Curtis, Vol. II, pp. 36–40, 47–50, and 343–348 respectively; and by Fitzpatrick and Wolford in this volume, pp. 238–243, and 47–53.

most interesting. To determine this you are each asked to make a list of no more than five things relating to science in which you are really

TABLE LXXXXI

RANKS OF DOMINANT INTERESTS OF FIVE HUNDRED THIRTY-SIX BOYS AND FIVE HUNDRED THIRTY-ONE GIRLS

Interests	Boys			Girls		
	Inferior	Average	Superior	Inferior	Average	Superior
Chemistry	1	1	1	11.5	4	4.5
Earth	2	7	15	6	10	7
Electricity	3	5	4	8.5		10
Animals	4	3	5	1	2	2
Aviation	5	4	2		9	10
Astronomy	6	2	3	10	1	
Sky	7			11.5		
Radio	8	8.5	6			14
Plants	9		7.5	2	3	3
Minerals	10	8.5	7.5		13	12
Air	11		9.5			
Mechanics	12.5	6	9.5			
Human body	12.5	11	12.5	4	7	6
Birds	14	13		7		
Stars		10	12.5	3	5	1
Moon		12		0	14	
Insects		14		5	8	4.5
Planets			12.5			13
Biology			12.5			
Flowers				8.5	6	8
Forests				13		10
Hygiene				14.5		
Fish				14.5		
Geology					11	
Botany					12	
Zoology					15	

most interested. Write one of the five topics you select after each number listed below.

"It will be noted that an earnest attempt was made to suggest as little as possible to the pupils."

"The pupils were asked to give their grade, age, and sex, but not their names. Space was also provided for the teachers to indicate whether the class was composed of superior, average, or inferior pupils from the standard of mental ability [as judged for the most part from the results of mental tests]. Not all pupils, of course, were able to express five interests." From the 1,067 papers returned, by 155 inferior, 157 average, and 219 superior girls, and by 143 inferior, 194 average, and 199 superior boys, 178 different scientific interests were tabulated.

Findings.—1. A consideration of the questions asked by these three groups of pupils, superior, average, and dull, reveals few instances of significant differences in the "progressive increase or decrease" of interest with increase of intelligence. "These progressive changes, however, are found more often in the case of boys than of girls."

2. "If the interests of inferior and of superior pupils are compared, omitting consideration of the average pupils, . . . the interests of the two groups of girls in astronomy, stars, planets, earth, weather, flowers, chemistry, radio, geology, hygiene, human body, zoology, birds, fish show appreciable differences. The same might be said for moon, earth, sky, weather, biology, chemistry, physics, aviation, telephone, oceans, insects, and agriculture in the case of the two groups of boys."

The ranks of these interests for the various groups are shown in Table LXXXXI.

STUDY NO. 212

Science Interests[1]

By Frederick Linder Fitzpatrick*

Problem.—To determine the factors which influence the responses of pupils in studies of scientific interests, as a means of determining the probable reliability of such studies.

Method.—A list of 100 "terms suggestive of the materials of science, at least in one or more of their usages," was selected from Thorndike's list of twenty thousand words. Approximately half the terms pertained to physical, and the rest to biological science. These terms, arranged in a column, were so grouped that from 5 to 11 consecutive ones related definitely to each of the following 11 categories: anatomy and physiology, largely of the human body; human diseases; ecology; economic biology; natural history, plants and animals; astronomy; climate and weather; geology; energy, its control and use; and applications of physical science in the home.

A second list of terms was prepared, each of which "matched" the corresponding item in the first column. In all cases the paired items were either synonymous or were "related in their implications."

"A third column was prepared in which all items were arranged in the form of questions" selected to "match" the items in the first and second lists. A fourth column was likewise prepared, "consisting of items which incorporated 'sales-

[1] For references to other studies of interests, see Footnote, p. 235, of this volume.

* Bureau of Publications, Teachers College, Columbia University, New York City, 1936. A report of this study appears under the title, "Pupil Testimony Concerning Their Scientific Interests," in *Teachers College Record*, XXXVIII (February, 1937), 381–388; and also as "Exploring Pupils' Science Interests," in *The School Executive*, LVI (June, 1937), 386–387.

manship' terms, such as 'dangers,' 'romance,' 'value,' 'wonders,' and 'mysteries.' " These items matched those in the preceding three columns. "Every word used in any column appears in the Thorndike list of 20,000 words . . ."

A sample of the four columns follows:

I	II	III	IV
breathing	respiration	How do we breathe?	The mystery of breathing.
toxins	antitoxins	Are toxins dangerous?	Interesting facts about toxins.
energy	power	From what sources do we obtain power?	Strange facts about energy.

The items in each column were "scrambled" and then were allocated to four final forms (designated as Forms I_1, II_1, III_1, and IV_1) by a "staggering" process such that each contained in each of its four columns 25 items matched by corresponding items from the three other original columns. Four more final forms (designated as Forms I_2, II_2, III_2, and IV_2) were prepared in exactly the same way as were the others except that the order of items was reversed. Thus, "the corresponding pairs of item-lists (such as Form I_1 and Form I_2) were identical, except for the order in which the items occurred."

The four forms of the first, and of the second group, were administered, respectively during the third week in October, 1935, and the third week in January, 1936, to six groups as follows: Group A, composed of 36 graduate students of both sexes in Teachers College, Columbia University, most of whom were majoring in some elective field of science, chiefly biology and the teaching of science; Group B, composed of 34 college students of both sexes in New College, of Teachers College, Columbia University, who were studying the elective survey course in science; and Groups C, D, E, and F, composed, respectively, of 37 girls in an elective tenth-grade class in biology, of 29 girls in an eighth-grade required class in general science, of

33 girls in a seventh-grade required class in general science, and of 30 fifth-grade boys and girls in a required course in science—all in the Horace Mann School, New York City.

The following directions were given with the item-lists:

Directions.—Print your name plainly on the line above. Below are a number of topics which might be studied in a science course. Read the entire list before you do anything else. Then underline at least twenty items that interest you, and that you would like to study. If you find that you are interested in more than twenty items, you may underline as many as forty. Try to be entirely fair and honest in making your decisions. Do not ask any questions about the items, but do the work to the best of your ability.

The four forms of each series were administered to the six groups with an interval of 15 minutes between each form and the next. "All the testimony of each student with respect to every item (whether scored or not) was recorded on specially designed data sheets" so arranged that the response of every pupil on each of the four forms for both the October and the January markings could be readily compared. Conclusions were based on the percentages of individuals in each of the six groups who gave consistent responses after the 15-minute and the three-month intervals; and of the responses of the members of Group A to 30 of the paired items originally in Columns I and II.

To study preference and the shifting of testimony, the data were transposed to new sheets "so that the items would be placed in their proper category relationships . . ." Decile rankings were then assigned to each group of four related items as follows: the 10 groups of items scored most frequently by the members of a given class received the rank, 10. The 10 groups of items scored least frequently by the members of that class received the rank of one. Thus, "variation in the size of the various groups is eliminated as a factor in the comparison."

These data were summarized by "averaging the decile rankings," to obtain an "indication of preference by categories for each student- or pupil-group."

To determine the extent to which the form in which the items was presented affected the response, the average scores of the six groups for each of the four types of items was computed on the basis of, respectively, four points for the most frequently scored type of items, three for the next most, etc.

A comparison of the members of the two sexes with regard to the consistency of their testimony was made by comparing the percentages of items marked in October and also in January by men and women or by boys and girls. Preference of the two sexes was determined by analyzing the expressed preferences of the individuals in Groups A and F with respect to the items of each category.

To determine whether word difficulty affects response, the responses to 25 pairs of words of obviously related meanings but of markedly different frequencies of use, were examined to note whether the group scored the word having the greater frequency most commonly, or *vice versa*.

Further comparisons were made to determine the relative degrees of interest in the different categories; "whether or not the various categories represent homogeneous groupings of subject matter upon the basis of 'interests' "; and whether there are characteristic interests for various grade levels or for different types of classes.

Findings and Conclusions.—1. "The average individual changed his or her testimony to a marked degree after a three-months' interval."

2. "Individual differences with regard to change of testimony after a three-months' interval were striking."

3. "Change of testimony after a three-months' interval was also characteristic of whole groups (classes), ranging in grade placement from the fifth grade to the graduate college."

4. "Responses of individuals or groups to *related* items at 15-minute intervals . . . may either have reflected a sad lack of understanding concerning work-relationships, even in the case of graduate students, or have suggested that much testimony of this nature is ill-considered."

5. "The testimony gave no more evidence of being well-considered when repeated after a 15-minute interval than when repeated after a three-month interval."

6. "Change of group testimony concerning categories of related items was just as characteristic as was change of testimony concerning specific items."

7. "The data as a whole showed no marked preference either for the things of biological science or for the things of physical science. However, there is every indication that such an apparent preference could easily be produced by a clever selection of items in advance."

8. "There was some evidence of consistency and stability in the responses to items in three of the categories, which were the preferred categories according to the testimony, but even in these cases there were numerous inconsistencies of individual testimony."

9. "The form of item used has some conditioning effect upon responses. This effect, however, is not as great as might be supposed, and it is by no means the only conditioning factor involved in the situation."

10. "No *material* sex differences were evident, either in the matter of supposed 'interests' or with regard to consistency of testimony."

11. "Comparative word-difficulty appeared to have been an important conditioning factor at the fifth-grade level. Above the seventh-grade level this effect was not apparent, except that the more advanced students . . . showed a preference for the *more difficult* terms."

12. "There is some evidence to the effect that, for reasons not brought out in this study, certain terms are likely to evoke

positive reactions and certain other terms to produce negative reactions, and that these results depend upon something quite apart from word-difficulty or form of item."

13. "The general inconsistency of the testimony makes any conclusion regarding comparative interests at different grade levels, or regarding the groups of subject-matter materials upon the basis of 'interests' of dubious value."

STUDY NO. 213

How Shall Science Instruction Be Organized?

By Archer Willis Hurd*

Problem.—To determine the criteria, plans, and features of organization of subject matter in elementary and high-school courses of science.

Method.—During the fall of 1933, a list of 29 criteria for "selecting and organizing subject matter in elementary and high-school science courses," based chiefly on material in the Thirty-first Yearbook of the National Society for the Study of Education, Part I,[1] and Downing's *Teaching Science in the Schools*,[2] was submitted to about twenty-five teachers of science. A list of 20 criteria, five plans, and eight features determined from the reactions of 12 of this group "who may be classed as quite expert in the field of science teaching" was submitted to 50 members of the National Association for Research in Science Teaching, 50 members of the Central Association of Science and Mathematics Teachers, and to 50 teachers in colleges, normal schools and departments of education in universities. These respondents were asked to evalu-

* *Science Education*, XVIII (April, 1934), 106–111.

[1] *A Program of Science Teaching*, Thirty-first Yearbook of the National Society for the Study of Education, Part I (Bloomington, Illinois: Public School Publishing Co., 1932).

[2] Elliot R. Downing, *Teaching Science in the Schools* (Chicago: The University of Chicago Press, 1925).

ate each item on a seven-point scale, designating respectively, in descending order, "Very Great," "Great," "Considerable," "Some," "Little," "Very Little," and "No" importance with respect to the designated criterion or desirability with respect to the designated plan or feature. By January 1, 1934, a total of 66 replies had been received, 21, 24, and 21 respectively from members of the N.A.R.S.T., of the C.A.S.M.T., and of the college group.

Computations were made of the "mean rating on each criterion, each plan, and each feature," for each of the three groups mentioned, and for a fourth group of 66 composed of the other three groups. In addition, S.D.'s, coefficients of variability (the rank in agreement of the judges was in the inverse order of these coefficients), and S.E.'s of the means were computed for each group of respondents and the items of each of the three categories, were ranked on the basis of the mean judgments on the seven-point scale. "In case mean ratings were the same for two or more items, the one having the lowest variability rating was ranked highest." The significance of the mean rating for each criterion was determined by dividing the mean rating by its S.E.

"In order to determine the significance of the discrimination shown by the 66 judgments of the various criteria, differences in mean ratings were found between the first and second, first and third, first and fourth, and so on. These differences were divided by their S.E.'s. A ratio of 3.00 was considered significant to indicate certainty of a true difference." Similar computations were made for both the plans and the features of organization. Coefficients of correlation were computed for the criteria and for the combined list of 33 criteria, plans, and features, between the responses of each group of judges and those of each other group. Critical ratios were likewise computed "for differences between mean ratings of contrasted groups" (N.A.R.S.T. and C.A.S.M.T., and each of these and the university teachers).

Table LXXXXII

Ranks, Mean Ratings by Sixty-six Judges, and Ranks in Agreement by These Judges, of the Criteria, Plans and Features of Organization with Respect to Courses of Science below the College Level

Criteria	Rank	Mean rating	Rank in agreement by judges
Science courses should be organized			
*To explain some scientific attitudes and show how they affect man's thinking (e.g., openmindedness, suspended judgment, etc.)	1	6.20	1
To explain the methods of science	2	6.05	2
So as to make an immediate and sustained appeal to pupils (interest)	3	5.76	6
So as to encourage the belief in, and practice of, desirable social ideals involving science (e.g., community co-operation in cleaning up rubbish)	4	5.74	4
So as to be of the most direct use to pupils in their everyday living (utility)	5	5.72	3
To explain directly the local environment of the pupil (e.g., the local electric light plant)	6	5.41	8
So as to be within the capacities of all pupils enrolled (individual differences)	7	5.38	12
So as to be within the abilities of all pupils enrolled (individual differences in capacities and former training)	8	5.32	10
So as to make a direct and immediate contribution to the welfare of our social order (e.g., injurious insects and their eliminations)	9	5.26	17
So as to stimulate discussions of problems related to science which are prominent in the news of the day (e.g., utilization of water power in the Tennessee River region)	10	5.17	5
So as to have unity and coherence as a whole	11	5.17	15
So as to enable pupils to spend adequate time on desirable hobbies related to science (leisure-time objective)	12	5.03	11
So as to provide for the exercise of creative imagination	13	5.00	1
So as to make direct contributions to wise vocational choice by pupils (vocational objective)	14	4.73	9
To explain aspects of the national environment not found locally (e.g., geological formations not found locally)	15	4.59	7
So as to stimulate in the pupil the sense of his own worthy achievement (for the purpose of preventing inferiority feelings)	16	4.52	14
To make maximum use of the personal equipment of the teacher in knowledge and training	17	4.28	18
To explain aspects of the world environment not found in the nation (e.g., animals of foreign countries)	18	4.15	13
To make maximum use of the school's facilities	19	4.08	20
To accord with the organization of the developed sciences, (e.g., physics, chemistry, geology, botany, etc.)	20	3.65	19
Plans of Organization			
A plan using major topics having large social implications and involving the solution of important social problems (e.g., "Our City Water System")	1	5.48	2

* Table LXXXXII is read thus: This criterion ranks first in importance; has a mean rating by 66 experts of 6.20 on a seven-point scale; and has the lowest coefficient of variability and hence the highest degree of unanimity of agreement by the judges.

TABLE LXXXXII (*Concluded*)

Criteria	Rank	Mean rating	Rank in agreement by judges
A plan using comprehensive generalizations of science in the forms stated by men of science most gifted in comprehensive insight in science (e.g., "The Sun is the Chief Source of Energy for the Earth")	2	5.09	5
A plan using personal individual problems related to science (e.g., "How I may Choose the Best Diet")	3	5.08	1
A plan using self-initiated individual projects related to science (e.g., "Building of a Radio Set")	4	4.38	4
A plan using group projects in science (e.g., "Planning an Auditorium Period")	5	4.05	3
Features of Organization			
An in-class program consisting of activities including assignment, study, discussion, reports, drill, recitation, explanation, demonstration, laboratory work, or such other activities as will best serve the learning process	1	6.15	1
Judgment of out-of-class activities by estimates of specific traits of character evidenced in the out-of-class work (e.g., initiative, self-reliance, systematization, etc.)	2	5.54	2
Judgment of in-class achievement from scores on valid, reliable, and comprehensive tests	3	5.53	3
Voluntary, out-of-class activities designed to be a part of the pupils' leisure-time programs. (The purpose is to give the pupils an opportunity to formulate an integrated leisure-time program and to stimulate voluntary work related to science.)	4	5.15	5
Judgment of out-of-class activities by estimates of value based on concrete results of such activities	5	4.86	4
An in-class program to be used for the definite learning of a carefully selected list of important subject elements in science possible for all pupils enrolled during the time taken for class meetings. (The purpose is to save out-of-class time for individualized activities.)	6	4.71	6
The saving of out-of-class time for voluntary individualized activities related to the in-class program. (This implies no assigned lessons (home-work) to use pupils' out-of-class time.)	7	4.23	7
A traditional, conventional, academic-lesson-giving and lesson-learning plan with home-work of a required kind	8	2.98	8

Further check computations of composite rankings and of coefficients of correlation were made on the basis of the 66 responses plus 24 additional responses received after January 1, 1934.

Conclusions.—"Considering all the data, there is evident a general consensus of opinion on criteria, plans, and features for the organization of instruction in science courses below the college level. This does not mean that all individuals agree with

the consensus—only that a group including from 35 to 45 will agree with another equal group selected in the same manner."

Table LXXXXII presents the significant facts with respect to the criteria, plans, and features.

STUDY NO. 214

Criteria for the Selection of Science-teaching Materials

By Cyrus W. Barnes*

Problem.—To determine (a) "the standards, factors, or criteria which control the selection of special equipment, supplies, apparatus, specimens, and other materials used in the teaching of general science, biology, chemistry, and physics in Grades VII to XII of public schools"; and (b) to evaluate these criteria.

Method.—The investigator read "more than one hundred courses of study and lists of teaching materials in science," together with the references cited by Pieper,[1] and the digests of studies contained in the two volumes of *Digests of Investigations in the Teaching of Science* by Curtis, in the search for criteria governing the selection of teaching materials in science. He found "no direct statements of such criteria, . . . and no indirect statements" except those implied in statements of the objectives of science instruction.

The investigator then entered into correspondence with 151 "specialists in science education" selected from (1) the editorial staff of *Science Education;* (2) authors of certain articles on

* Dissertation for the degree of Doctor of Philosophy, New York University, 1935. This digest is made from a report of this study in *Science Education*, XIX (December, 1935), 152–157.

[1] C. J. Pieper, "Research Studies Related to the Teaching of Science," *Science Education*, XVI and XVII (October and December, 1931, February and April, 1932, and April, 1933), 55–65, 140–148, 233–237, 297–302 and 138–150, respectively.

science laboratories, laboratory methods, objectives, experiments, teaching materials, and related subjects, listed in the *Education Index* from January, 1929, to January, 1933; (3) chairmen and advisors of committees on courses of study in science; (4) state and city supervisors of science; (5) manufacturers of science equipment, apparatus, and supplies; (6) and authors of science textbooks and laboratory manuals for secondary schools. One hundred eight replies were received and from these replies a tentative list of criteria was made.

These tentative criteria were submitted to 65 of those who had answered in detail the first inquiry, and to 55 additional ones. This total of 120 individuals included 33 members of the N.A.R.S.T. These individuals were requested to indicate their judgments of each criterion as (1) "Necessary or essential to wise selection of science-teaching materials; (2) Advisable though not always significant; or (3) Invalid, or not sufficiently important to deserve consideration in the selection of science-teaching materials." Eighty complete evaluations were received.

The investigator next considered "each criterion in terms of relevant principles and practices of science teaching, derived from the literature on science teaching . . ." This procedure resulted in several groupings of the criteria; (1) those that "may be applied with few data other than those involved in general familiarity with the local teaching situation . . ." (as numbers 4, 5, 10, 13, 16, 17, 19, and 21, and "in a superficial but useful way," numbers 11, 12, 14, 15, 20, 26, and 28"); (2) those that "should, if used at all, be applied in the light of research . . . and of authoritative treatises on science education," (as numbers 1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 18, 22, 23, 24, and 25); and (3) those that "may be considered apart from other criteria, not on the basis of the degree of difficulty involved in their application, but because of their being somewhat dependent upon, or somewhat conditioned by Criterion Number 1" (as numbers 3, 6, 8, 10, 12, 14, 15, 16, and 22).

Findings.—(1) The list of criteria follows:

CRITERIA FOR THE SELECTION OF MATERIALS FOR THE TEACHING OF SCIENCE[1]

*1. Contribution to the attainment of the objectives of science instruction
*2. Suitability and significance to the principle under discussion
3. Significance of the principle under discussion
†4. Enrollment of science classes compared to that of other classes
*5. Funds available for the purchase of science materials
6. Contribution to the understanding of the scientific method
7. Whether price is commensurate with the learning products attainable through use of the item
8. Contribution to the attainment of scientific attitudes and appreciations
9. Contribution to pupils' interests in the subject
*10. Requirements of the course of study
†11. Type of course, as vocational compared with college entrance
*12. Type of laboratory work, as demonstration compared with individual experimentation
†13. Number of different courses in science in the school
14. Methods of organization and presentation of subject matter
15. The extent of use of visual aids
*16. The experiments which have been selected for use
17. Location of the school, i.e., opportunity to study scientific phenomena at primary sources
18. Ease of improvisation of substitute apparatus
19. Frequency of use of the teaching material
20. Ease of assembling and ready availability when needed
†21. Teachers' ability and willingness to use the apparatus
22. Relation of the apparatus to probable experiences of pupils' lives
*23. Suitability to pupils' needs, i.e., not needlessly complicated or fancy
24. Economy of time and energy in teaching a concept
25. Teachability of the concept without experimentation
26. Rate of depreciation of the article
27. Ease of caring for and storing the article
28. Economy of time and energy of the teacher

[1] The criteria marked with an asterisk (*) were judged essential by 60 per cent or more of the evaluators; those marked with a dagger (†) were judged "not valid" by 20 per cent or more of these evaluators.

Conclusions.—1. Certain criteria "may be applied in the light of pertinent information found in published research."

2. Certain criteria "can be used only on the basis of subjective judgment of the degree to which any specific item of teaching material will satisfy a given criterion."

3. The selection of science-teaching materials should be made by some one familiar with the local course of study, with its objectives, and with the principles of selection and organization of subject matter used in its preparation."

4. "More research than is now available is needed on certain important problems in science teaching in order to make possible the most successful application of each of the criteria herein recorded, to actual cases of selection of science-teaching materials."

5. "It is important that the person or persons responsible for the selection of science-teaching materials be familiar with published research relating to science education." "This last conclusion . . . seems to the investigator to be of greatest importance among these conclusions."

STUDY NO. 215

Lists of Essential Apparatus for Use in High-school Sciences

By T. C. Holy* and D. H. Sutton

Problems.—(1) "To develop a list of laboratory apparatus essential in teaching a class of 24 pupils in each of the [four] major high-school sciences, with the individual items arranged upon the basis of their relative importance; (2) to furnish some index of the cost of providing these essential items of laboratory apparatus in each of the four major sciences; and (3) to show the instances of overlapping among items of

* Columbus, Ohio: Ohio State University Bureau of Educational Research Monographs, No. 12, 1931.

apparatus necessary to conduct a class of the indicated size in biology, chemistry, general science, and physics."

Method.—The items of apparatus for each of the four major branches of high-school science, biology, chemistry, general science, and physics, were obtained from several sources: (1) the recommended lists published by 34 state departments of education; (2) the lists of laboratory apparatus contained in four laboratory manuals of biology (published between 1920 and 1929), four, of chemistry (published between 1926 and 1930), five, of general science (published between 1917 and 1930), and seven, of physics (published between 1923 and 1929); and (3) the lists contained in *Laboratory Layouts for the High-School Sciences.*

The items secured from these sources "were then grouped under two major headings, individual and general, each item being tabulated under the same heading as that under which it appeared in the primary source. By this division there were included under the Items of Individual Apparatus the materials to be supplied to each pupil in performing the individual laboratory exercises in the respective science courses, while under Items of General Apparatus were included all those items employed by the teacher or by a group of students when demonstrating certain scientific experiments not designated as individual exercises." A checklist of the items of apparatus in each of the four sciences was next made by selecting from the entire list for that science, those items "appearing in 20 per cent or more of the sources originally analyzed." These checklists included for chemistry, physics, biology, and general science respectively 75, 167, 67, and 77 items of general apparatus; and respectively 80, 184, 35, and 68 items of individual apparatus, with a sufficient number of pieces of each item to serve the needs of a class of 24 pupils.

These lists for the four subjects were submitted to respectively 286, 251, 273, and 219 teachers of these respective subjects in 35 states. These teachers were asked to indicate

in the appropriate column provided, whether each item was "Necessary," "Desirable but not Necessary," or "Unnecessary," to indicate the correct number of each of these items to be supplied, if the number suggested for that item were not correct, and to add other items not included, which they thought necessary.

Usable replies were received from respectively 84, 81, 78, and 76 per cent of the teachers of general science, of physics, of chemistry, and of biology to whom check lists were sent. These respondents were chiefly secondary-school teachers, but many were heads of departments and supervisors of science in high schools, or (except for general science) teachers of science in colleges, junior colleges, teachers' colleges, and universities.

". . . a rank was assigned to each item of apparatus by calculating the percentage of the teachers replying who regarded each item 'Necessary,'" and the items were arranged in the descending order of importance as indicated by the ranks assigned. An "index of the price" of each item was next determined by submitting the apparatus lists in each of the sciences to four leading science-equipment companies with the request that they list the highest price per item and the highest total price, exclusive of freight, for the quantity of any individual item desired. "The average of the prices submitted by the four companies was then listed with each item, together with the cumulative price."

"The final step was to determine the overlapping in the pieces of apparatus necessary to conduct a class of 24 pupils in each of the major science subjects; that is, the pieces of apparatus which would be used in teaching other sciences."

The results of this study are presented in four extensive tables, one each for general science, biology, chemistry, and physics, and each providing for the needs of a class of 24 pupils.

Findings.—The list for biology contained 35 items of individual apparatus, and 67, of general apparatus, costing in

all, respectively $688.66 and $351.94; that for chemistry contained 80 items of individual apparatus, and 75, of general apparatus, costing in all, respectively $397.44 and $386.96; that for general science contained 68 items of individual apparatus, and 77 of general apparatus, costing in all, respectively $370.00 and $202.53; and that for physics contained 184 items of individual apparatus, and 167 of general apparatus, costing in all, respectively $1,956.91 and $642.96.

A sample of the final lists follows:

LIST OF ITEMS, RANKINGS, OVERLAPPING, AVERAGE HIGHEST TOTAL PRICE, AND CUMULATIVE PRICES FOR BIOLOGY APPARATUS

Items of apparatus	Number of items	Percentage of those checking the item as			Other lists in which item occurs*	Highest average total price	Cumulative price total
		Necessary	Desirable	Unnecessary			
Items of Individual Apparatus							
Microscope slides 3 × 1″	72	91	6	3		$ 1.44	$ 1.44
Test tubes, 6 × ¾″	24	91	5	4	G-C	.72	2.16
Magnifiers (tripod)	24	90	9	1	G	16.80	18.96
Oz. microscope cover glasses	4	90	8	2		6.40	25.36
Dissecting sets	24	87	10	3	G	48.00	73.36
Items of General Apparatus							
Package corks, assorted, 0–11	1	91	8	1	G-C-P	.75	.75
Box labels, No. 201	1	89	10	1		.09	.84
Microscope slides, blanks, 3 × 1″	36	87	8	5	G	.36	1.20
Box microscope slide cover glasses	1	85	9	6	G	.80	2.00
Set weights, with holder, 10–500 gr	1	83	14	3	G-C-P	3.25	5.25

* In this column G indicates general science; C, chemistry; and P, physics.

STUDY NO. 216

Factors Influencing the Common-science Knowledge of High-school Pupils

By Orlie M. Clem* and Joseph J. Dudleston

Problem.—"To determine the relation of certain specific factors in the pupil's school and out-of-school environment, to his functional knowledge of common science."

Method.—This study involved 1,070 pupils who were enrolled in 40 classes of science in the Utica Free Academy of Utica, New York. These pupils were "distributed by subjects as follows: biology, 577; chemistry, 227; physical geography, 43; and physics, 223." Data were secured from responses to a questionnaire, from school records, from personal interviews, and from scores on a multiple-response test of 50 items "couched in non-technical language" and measuring "functional knowledge of everyday situations in common science." Comparisons were made of the average test scores of various groups of these pupils selected on the following bases: age; sex; curriculums in which the pupils were enrolled; numbers of courses of science they had already studied; school marks; membership or non-membership in a science club; possession or non-possession of a workshop or a laboratory at home; high-school subjects preferred; expected occupations; whether or not they had out-of-school employment; amount of education possessed by their parents; the occupations and nationalities of their fathers; and sizes of families from which the pupils came.

Conclusions.—1. "A pupil's knowledge of common science consistently increases with the amount of science passed."

2. "There is a definite positive relationship between knowledge of common science and age."

3. "Boys rank much higher than girls in knowledge of common science."

* *Science Education*, XVII (December, 1933), 267–272.

4. "Pupils in the scientific curriculum are considerably superior to those in non-science curriculums."

5. "There is a definite positive relationship between general school marks and knowledge of common science."

6. "Science club members excel non-members; likewise, those with a workshop or laboratory in the home, excel those who are without one."

7. "Pupils who prefer science as a subject excel those who do not; likewise, those who expect to pursue an occupation in the field of science . . . [excel] those who do not."

8. "Pupils who work regularly outside of school excel those who do not."

9. "Knowledge of common science is positively related to the amount of education possessed by parents."

10. "Children of smaller families excel those of larger families in common science knowledge."

STUDY NO. 217

Extensive Reading *versus* Intensive Textbook Study as a Means of Acquiring a Knowledge of Scientific Facts[1]

By Ralph Samuel Rice*

Problem.—To determine whether pupils acquire a knowledge of a greater number of facts from required extensive reading in addition to intensive study of science than they may obtain from intensive textbook study alone.

Method.—Pupils who were studying science in three Pennsylvania high schools were equated on four bases: I.Q. (as deter-

[1] See also studies of extensive reading by Curtis, *Investigations in the Teaching of Science*, Vol. I, 106–111 and 115–116.

* Dissertation for the degree of Doctor of Education, Pennsylvania State College, 1935. A report of this study under the same title appears in *Journal of Experimental Education*, IV (June, 1936) 376–402.

mined in one school from scores on the Otis Self-administering Tests of Mental Ability, Intermediate and Advanced Forms; and in the other two schools from scores on the Kuhlman-Anderson Intelligence Tests); previous attainment in science (as determined from scores on the science section of the Sones-Harry High-school Achievement Test); grade in school; and sex. "Home conditions, access to reading materials and libraries, extracurricular activities, and home duties were taken into consideration when possible to do so, or when such information was available. Arbitrary variations of three points in I.Q. or three percentiles in science achievement were allowed in matching pairs."

"In all, 2,500 pupils participated, of whom 854 pairs lent themselves to favorable matching." Since the investigation was continued for four years in School No. 2, some pupils in that school participated for only one year, and others for two, three, and even four years. During the four years, therefore, respectively 36, 49, 36, and 36 pairs studied general science in School No. 2, and 121 pairs studied general science during one year in School No. 3; similarly, 36, 36, 49, and 36 pairs, respectively, studied biology during the four years in School No. 2, and 100 pairs studied that subject in School No. 3 during a single year; 30 pairs in School No. 1 and 64 pairs in School No. 3 studied chemistry during one year; 36 pairs studied chemistry in School No. 2 during each of two years; 36 pairs studied physics in School No. 2 during each of two years, and 81 pairs studied that subject in School No. 3 during one year.

The control (C-) sections were taught by the daily-recitation plan in Schools Nos. 1 and 3, and by a modified form of the Morrison Unit Plan in School No. 2. The experimental (X-) sections were taught by the same methods as those used with the C-sections but in addition were assigned readings both general and specific, in scientific books, magazines, and other periodicals. "The pupils had more or less freedom in the matter of selecting the sources of their outside reading. The school

libraries were at their disposal and they were permitted to read any other materials which they might find in the fields of science. The pupils were encouraged to bring clippings of items of interest and present them for class discussions." In order to discourage somewhat the "mere use of scissors, the pupils were required to mark or to report by written comment the chief items of interest in the clippings as well as their scientific value." Records of readings and clippings were kept by a class "secretary." The materials thus compiled in notebook form were available at all times for perusal or study by the members of the X-sections. Each X-pupil was required to contribute a minimum of 125 items per year.

Tests of factual information were administered at the beginning of each unit and again at the end or at the examination period in every group. With units for which published tests were not available, teacher-made tests were used. The reliabilities of these tests determined by the Pearson Product-moment Method of split halves were uniformly high. The validity of each test was determined or confirmed by comparing and checking the items with the *Pennsylvania Course of Study*,[1] with also at least five different textbooks in that subject, and with the objectives listed in the courses of study in the several schools. Chemistry test items in School No. 3 were also checked with Wray's list.[2] "The tests were also submitted to a committee of five science teachers. All questionable items were then eliminated prior to administering the tests."

To test relative retention of materials, a test of 250 items was administered in School No. 2 to two matched sections of biology and a similar test to two matched sections of general science.

"At the end of each year of the experiment [in School No. 2], comprehensive tests involving the magazine and periodical

[1] Bulletins 73 and 74, Department of Public Instruction, Harrisburg, Pennsylvania.

[2] See pages 164–168 of this volume.

material read were given to the participants of the experiment. These tests consisted of a battery arrangement of 500 items. The items included current science, recent discoveries or practical applications of scientific facts as described in the magazine articles. An effort was made to include only those items which were not included in the regular course of study or in the textbooks in use.

The results of the experiment were determined by computing the ratios of the differences in mean gains to the standard errors of the differences in mean gains.[1]

Further comparisons were made by combining all the X- and all the C-pupils from all the groups for each subject in School No. 2. The data from these combined groups were treated in the same manner as that for the smaller groups.

Findings.—1. The "X-pupils read approximately 2.8 times as much as the C-pupils. The scientific topics reported by them show that the reading was of . . . general reference material."

2. "In tests dealing with the subject matter included in the course of study of the several subjects, the X-group exceeded their mates on 59.8 per cent of the trials, and scored equally with them on 6.7 per cent of the trials. The C-group excelled the X-group on 33.5 per cent of the trials."

3. On the whole the differences in favor of the X-groups were statistically significant.

4. The X-pupils of the special paired groups in School No. 2, knew 197 items more than the corresponding pupils of the C-group in the tests on magazine articles. "These items were additional to the superiority in course items previously indicated."

5. The results of the tests for retention showed an advantage in favor of the X-groups.

[1] C. C. Peters, and W. R. Van Voorhis, *Statistical Procedures and Their Mathematical Bases* (State College, Pennsylvania: The Pennsylvania State College, 1933), p. 147.

6. "Boys excelled girls in general science and physics, but the two sexes were approximately equal in biology and chemistry."

7. "The extensive-reading program was preferred by the majority of the X-pupils."

Conclusions.—1. "Extensive reading of scientific materials is a significantly effective method of acquiring a knowledge of scientific facts."

2. "The knowledge of facts and the rate of acquiring them increases with the maturity of the students."

3. "All other things being equal, the method of instruction makes little difference in the effectiveness of extensive reading."

4. "Boys exceed girls in a knowledge of scientific facts."

5. "The pupils' reading of scientific materials supplementary to the textbook is mostly of general reference nature."

6. "Many pupils prefer extensive reading to intensive textbook study."

7. "Extensive-reading pupils remember more scientific facts than do the intensive-study pupils."

8. "Extensive-reading pupils learn a number of additional scientific facts which are not learned by the intensive-study pupils."

STUDY NO. 218

Teaching Values of Common Practices in Correcting Examination Papers—a Second Study[1]

By Francis D. Curtis* and Wesley C. Darling

Problem.—To determine which of four common methods or practices employed when pupils correct examination papers

[1] The first study, comparing pupil correction with teacher correction, appears in *Investigations in the Teaching of Science*, Vol. II, pp. 362–366. See also study by Lingren, pp. 264–267 of this volume.

* *The School Review*, XL (September, 1932), 515–525.

consisting of certain types of short-answer test items, serves the pupils best with respect to gaining and retaining a knowledge of scientific facts and the ability to apply such factual information in problem situations.

Method.—This investigation was conducted with 144 pupils in nine classes (two each in seventh-grade general science, ninth-grade elementary biology, tenth-grade general biology, and eleventh-grade chemistry, and one in eighth-grade general science) in the University of Michigan High School.

The four practices are as follows: "Under Method I, each pupil, as the teacher gave the correct responses, marked a check on his own paper opposite the number of every item to which he had made an incorrect response. Under Method II, each pupil, as the teacher read the correct responses, checked every incorrect response on his own paper as with Method I, and in addition, he wrote in the necessary corrections of each item to which he had made an incorrect response. Under Methods III and IV exactly the same procedures used in Methods I and II were followed, respectively, except that each pupil indicated the incorrect items or made the necessary corrections on another pupil's paper instead of his own." After the correction of the papers under Methods III and IV, the papers were returned to their respective owners so that each pupil might learn what errors he had made and how these errors should be corrected. Under all four methods the members of the class were encouraged to engage in a free discussion of every item." ". . . during the school year preceding the investigation the pupils had been given extensive and approximately equal practice with all four methods."

"The examination for each class was prepared as follows: The investigators prepared 120 or more test items of the completion, modified true-false,[1] multiple-response, and modified

[1] Howard Y. McClusky and Francis D. Curtis, "A Modified Form of the True-false Test," *Journal of Educational Research*, XIV (October, 1926), 213–224.

multiple-response types.[1] From these test items, four test sheets were prepared as nearly identical in form and difficulty as they could be made without actually trying them with pupils. Corresponding items on the four test sheets were questions of the same types." The sheets were clipped together in the same sequence but so that one-fourth of the pupils began with each sheet.

"The teacher examined the answers given on Sheet 1, representing Method I; he noted the errors and recorded on a separate sheet, with the name of the pupil, the item number of each incorrect response but made no marks of any kind on the examination sheet itself. He did likewise with Sheets 2, 3, and 4, representing Methods II, III, and IV respectively." This plan provided a check on the accuracy of pupil correction of their own and each other's papers. "In the computation of these percentages of error, it was assumed that the pupil made an error in correction whenever his marking of an item, either as correct or incorrect, differed from the previous marking of the same item by the teacher."

"During the first regular class period following the examination, the four sheets were distributed to the pupils, a set at a time. After each set of sheets was treated in the manner prescribed for it, this set was collected before the next set was distributed."

"On the following day fresh copies of the four sheets were again administered to each class without previous warning as a test of immediate recall. Four weeks later fresh copies of the four sheets were administered a third time without previous warning as a test of delayed recall, or retention. During the interval between the correction and discussion of the original sets and the final test, care was taken to give no review or drill on the work covered by the examination."

[1] Francis D. Curtis and Gerald G. Woods, "A Study of a Modified Form of the Multiple-response Test," *Journal of Educational Research*, XVIII (October, 1928), 211–219.

In order to determine the relative values of the four practices, the initial-test scores on all four sheets for each class were made equal with respect to both means and S.D.'s by eliminating from consideration the data for certain test items. The relative values of the four methods were then determined for both immediate and delayed recall by dividing the difference in means on two sheets representing two practices by the S.D. of the difference in means.[1]

Findings.—1. With respect to immediate recall, "the results secured with Method II were, in all but two classes, consistently superior to those secured with the other three methods." None of these results, however, indicated "practically certain" superiority except that of Method II over Method IV when the data from the whole nine classes were combined.

2. With respect to delayed recall, "the differences between the results secured with the four methods are neither so great nor so consistent . . . as in the case of the tests for immediate recall. The advantages which were found in favor of Method II in the test for immediate recall tended to diminish or even to disappear when the interval between the learning activities with the tests and the measuring of the values from these activities was lengthened from one day to four weeks." While the data "may be said to show, on the whole, a slight advantage in favor of the two methods of self-correction over the corresponding methods by which the pupil corrects another pupil's paper, these advantages are not consistently in favor of any method and in no case are sufficient to indicate more than a 'possible' superiority of one method over another."

[1] The following partial formula was used:

$$\text{S.D.D.}_M = \sqrt{\left(\frac{\text{S.D.}_1}{\sqrt{N_1}}\right)^2 + \left(\frac{\text{S.D.}_2}{\sqrt{N_2}}\right)^2}.$$

"The complete formula would increase only slightly the value obtained by this formula."

3. The average percentages of errors of the nine classes in marking by the four methods varied from .48 to 5.37 per cent; these average percentages of error were in two-thirds of the cases less than 3 per cent. ". . . the accuracy of pupil marking as here measured is greater under the two methods by which each pupil marks the paper of another pupil than under the two methods by which he marks the incorrect items on his own paper." ". . . on the whole, the older pupils were somewhat more accurate in their markings under all four methods than were the younger pupils."

Conclusions.—1. If immediate recall is the goal desired from these four uses of examination papers for *teaching* purposes, "then there are statistically significant advantages in favor of the two methods by which a pupil corrects his own paper over the corresponding methods by which each pupil corrects another pupil's paper. The method by which each pupil both checks and corrects the incorrect items on his own paper is, moreover, somewhat superior to that by which he merely checks the incorrect items on his own paper."

2. "If retention of knowledge is the goal desired, however, then the advantage of any one of the methods over any of the other three is not sufficient to justify its use to the exclusion of the other three methods of correction; that is, the learning values are about equal whether the pupil corrects his own paper or corrects another pupil's paper, provided the items are discussed one by one during the correction period, and provided also, that, under the two methods by which the pupils correct other pupil's papers each pupil has the opportunity subsequently to examine and discuss the corrections on his own paper. Moreover, the somewhat greater amount of time required to check the incorrect items and to write in the necessary corrections in excess of the time required simply to check the incorrect items is not justified in the light of the results obtained by this investigation."

3. ". . . the degree of accuracy with which the pupils were able to detect and to correct errors under each of the four methods is probably sufficiently high to justify the use of any of the methods."

STUDY NO. 219

The Relative Instructional Values of Four Methods of Correcting Objective Tests in High-school Chemistry[1]

By Vernon C. Lingren*

Problem.—To determine "as objectively as possible," the relative instructional values with respect to pupil learning and retention of subject-matter information, of four methods of correcting objective tests in high-school chemistry.

Method.—This experiment was conducted with four classes in chemistry in the Newton, Iowa, Junior-senior High School, during the year, 1932–33. Four test sheets, each containing 10 true-false, 10 multiple-response, and 10 matching items were prepared for each semester. These sheets, clipped together in sequence so that one-fourth of the pupils began with each sheet, were administered to each class respectively at the end of the eleventh week of the first semester and at the end of the tenth week of the second semester.

The following methods of correcting tests were utilized:

Under Method I the pupils merely checked all the incorrect responses. In the subsequent 30-minute supervised study period they were asked to write in the proper places on their papers, the corrections for the items which they had missed, and on the reverse side of the sheet to write a brief statement giving an explanation of the answer to each item missed.

[1] Compare this study with that of Curtis and Woods, *Investigations in the Teaching of Science*, Vol. II, pp. 362–366; and with that of Curtis and Darling in this volume, pp. 259–264.

* *Science Education*, XIX (October, 1935), 123–127.

"Individual help was given by the instructor upon request from the pupil. The papers were turned in at the end of the study period for partial added credit. The papers did not leave the room at any time."

"Under Method II, the pupils checked the incorrect responses on their own papers as the teacher read the correct ones and made a statement of facts about each item. Further questions from the pupils were encouraged, but the instructor did not prolong the discussions unless the class raised these questions."

Under Method III, the teacher checked all incorrect responses on the papers before returning them to the pupils. Also, he indicated the correct answers and added brief notes of explanations, equations, and page references to the textbook. He then discussed the items one at a time with the class, but if no questions were raised about a given item no further discussion took place.

Method IV was identical with Method III except that "the items were not discussed one at a time, but instead, the discussion was limited to such questions as arose from these directions by the teacher, 'I have marked the correct responses on your paper for those items you have missed. Note your errors and ask any questions you wish to about them.' "

Preceding the experiment, the pupils were given enough practice with each method to enable them to proceed without hesitation on all four methods of the study.

During the third class period following the initial test, the original test was administered without previous warning as a test of immediate recall. Six weeks later, without review or announcement, the same test was administered again to test retention of subject-matter information.

In order to determine the relative values of the four practices of correcting examination papers, it was necessary to make equal the means of the initial-test scores on all four sheets for each class. To accomplish this, the data for certain test items were eliminated from consideration. Thus, "in a given class

an equal number of each type of item were discarded from each of the four sheets. These deleted items were likewise eliminated from consideration in the tests of immediate and delayed recall."

The reliability of the differences in mean gains for the four methods was determined by dividing the differences in mean gains by the standard deviations of the differences in mean gains.[1]

To determine the accuracy with which pupils are able to correct their own papers, the sum of the errors made by the pupils on each sheet was divided by the product of the number of pupils in the class and the number of test items on that sheet, and then the result was multiplied by 100 to obtain the percentage of incorrect responses.

Findings.—1. For immediate recall, "the superiority of Method II over the other three methods was quite evident. Likewise, the inferiority of Method IV was evident, while Methods I and III were of intermediate value."

2. When evaluated on the basis of delayed recall, "the superiority of Method II over the other three methods was again evident . . . Method IV was likewise shown to be inferior to the other methods. Method III surpassed Method I slightly . . . Whereas these results are practically the same as those obtained in the immediate recall test, the differences were not quite so great in the delayed recall test. That is, the advantages of Method II over rival methods diminished somewhat during the intervening period of six weeks."

3. Pupil corrections were more accurate by Method I than by Method II, though, "the average error for both methods was below 1 per cent for both semesters."

Conclusions.—1. "In so far as the results of this investigation may be indicative, . . . Method II is the most conducive

[1] $$\frac{D_M}{\text{S.D.D.}_M} = \frac{M_1 - M_2}{\sqrt{\left(\frac{\text{S.D.}_1}{\sqrt{N_1}}\right)^2 + \left(\frac{\text{S.D.}_2}{\sqrt{N_2}}\right)^2}}.$$

to pupil learning and retention of subject-matter information."

2. ". . . the practice of having pupils correct their own test papers . . . is justified, when considered from the standpoint of accuracy."

3. "If the elements of time, interest, and instructional value are all considered, the practice of having objective tests corrected by the pupils in class is worthy of consideration by teachers in the secondary schools."

STUDY NO. 220

A Determination of the Scientific Attitudes

By Francis D. Curtis*

Problem.—To secure a list, as complete and as definite as possible, of the scientific attitudes.

Method.—An analysis was made of such books as Pearson's *A Grammar of Science*, Dewey's *How We Think*, Kramer's *The Method of Darwin*, and others dealing with the philosophic phases of scientific thought, for the purpose of securing a list of scientific attitudes. The search revealed a considerable number which in outline form were submitted to 50 high-school and 50 college and university teachers of science. These specialists in the subject matter of various fields of science were requested to mark *E* each item which they considered an essential one in

* Dissertation for the degree of Doctor of Philosophy, Contributions to Education, No. 163. New York: Teachers College, Columbia University, 1924, 41–49. A report of this investigation is found in *Journal of Chemical Education*, III (August, 1926), 920–927. A digest of the investigation of the development of scientific attitudes in high-school pupils appears in *Investigations in the Teaching of Science*, Vol. I, pp. 112–116.

A request was made by members of the N.A.R.S.T. who evaluated the first bibliography (see Preface) and was subsequently approved by 23 of the 30 evaluators of the second bibliography and disapproved by none, that this study be here included with others relating to the determination of scientific attitudes.

a complete list of scientific attitudes; to mark *D* each item which they considered highly desirable but not essential in such a list; and *U* each item which they considered unnecessary or undesirable in such a list. The evaluators were invited to write in such changes and corrections as they thought desirable, and to add any omitted points or items which they considered essential.

Fifty-eight replies were received. These varied from acceptance, with a note of commendation, of all the points and subpoints, to one letter which alone expressed dissatisfaction with the entire outline. Few of the replies, however, contained unfavorable comments; most of the comments suggested minor changes in the wording of the various statements of scientific attitudes.

Not all the judges evaluated each head and sub-head separately as requested. Some marked only the main headings and failed to score the sub-points, while a few others scored only the sub-points, where there were any, leaving the main topics unevaluated. In all such cases the investigator arbitrarily decided to assign to each unmarked item the same evaluation as that assigned to its immediately related main or sub-point.

Six additional attitudes were suggested as main or subordinate ones by various evaluators. Changes from the original list, however, were made only when the same recommendation was clearly advocated in two or more of the replies; or when the wording suggested was an obvious improvement on the original, without changing the original idea.

Findings.—The final revised outline of the scientific attitudes follows:

THE SCIENTIFIC ATTITUDES[1]

I. Conviction of universal basic cause and effect relations, rendering untenable
   1. Superstitious beliefs in general, as "signs" of "good or bad luck," and charms;

[1] For additional scientific attitudes determined by Craig, see *Investigations in the Teaching of Science*, Vol. II, p. 43.

2. "Unexplainable mysteries";
3. "Beats all" attitude, commonly revealed by
   (a) Too ready credulity.
   (b) Tendency to magnify the importance of coincidence.

II. Sensitive curiosity concerning reasons for happenings, coupled with ideals
   1. Of careful and accurate observation, or of equally careful and accurate use of pertinent data previously collected by others;
   2. Of patient collecting of data;
   3. Of persistence in the search for adequate explanation.

III. Habit of delayed response, holding views tentatively for suitable reflection varying with the matter in hand,
   1. To permit adequate consideration of possible options;
   2. To permit a conscious plan of attack, clearly looking forward to a prediction of the probable outcome or solution.

IV. Habit of weighing evidence with respect to its
   1. Pertinence;
   2. Soundness;
   3. Adequacy.

V. Respect for another's point of view, an open-mindedness, and willingness to be convinced by evidence.

STUDY NO. 221

The Measurement of Scientific Attitudes

By Ira C. Davis*

UNIT I

Problem.—To determine the philosophy and the objectives of science teaching which will contribute to the general philosophy, "Education is recognized as growth through problem solving so that the individual will act in such a way that he will make the greatest contribution to society and at the same time receive the greatest personal satisfaction."

Method.—The Wisconsin Science Committee, consisting of six members with the author of this report as Chairman, "organized more than three hundred fifty teachers into 55

* *Science Education*, XIX (October, 1935), 117–122.

different groups." Summaries of reports of the separate meetings of these groups were sent at regular intervals to the group leaders. The committee members attended meetings with 30 of these groups. "After a year's discussion, the committee met for three weeks and wrote the philosophy of science teaching."

Findings.—1. ". . . the purpose of science is to develop the ability in the individual to solve the problems that confront him. To do this, he will need (1) a scientific attitude, (2) a scientific method of procedure, and (3) a fund of information which will make it unnecessary for him to repeat what scientists have done before him."

2. The specific objectives of science teaching are:

Command of factual information
Familiarity with laws, principles, and theories
Ability to distinguish between fact and theory
Concept of cause and effect relationship
Ability to make observations
Habit of basing judgment on fact
Ability to formulate workable hypotheses
Willingness to change opinion on the basis of new evidence
Freedom from superstitions
Appreciation of the contributions of science to our civilization
Appreciation of natural beauty
Appreciation of man's place in the universe
Appreciation of the possible future developments of science
Possession of interest in science

UNIT II

Problem.—To determine what is the scientific attitude.

Method.—An analysis was made of the literature presenting "characteristics which might be considered as elements of a scientific attitude." ". . . this list of characteristics, with a few more added which were contradictory to each other," was sent to 250 well-trained, experienced teachers, 100 of whom taught in Wisconsin and the rest in various other parts of the United States. Of 162 replies received, 92 were "kept for

final statistical treatment." The characteristics were ranked in the order of the percentage of the evaluators who considered each a characteristic of the scientific attitude. An individual was then considered by the Committee to possess a scientific attitude provided he possessed the characteristics, abilities, and habits suggested by the five most highly rated attitudes.

Findings.—The characteristics of the scientific attitude with the percentage of the evaluators who considered each a characteristic are:

Willingness to change opinion on the basis of evidence (92 per cent)
Search for the whole truth regardless of personal, religious, or social prejudice (89 per cent)
Concept of cause and effect relationship (86 per cent)
Habit of basing judgment on fact (85 per cent)
Power or ability to distinguish between fact and theory (82 per cent)
Freedom from superstitious beliefs (81 per cent)

UNIT III

Problem.—To devise valid tests of possession of the concept of cause and effect relationship and of the ability to distinguish between fact and theory, and with these tests to determine whether Wisconsin pupils and teachers possess these characteristics of the scientific attitude.

Method.—A test of 66 items was constructed to test the possession of the cause and effect relationship. Each item consisted of a pair of statements such as these: "The sun shines on the earth; the earth is warm." "A boy often picked up toads; the boy had warts on his hands." The directions were to judge each of the paired occurrences by checking it as:

A—if the first occurrence is practically the sole cause of the second

B—if the first occurrence is one of a number of the important contributing causes of the second

C—if the first occurrence contributes only slightly to the second

D—if both occurrences are results of the same general cause or causes

E—if the first occurrence bears no causal relationship to the second

The mimeographed test was administered to 295 pupils in six high schools and also to some teachers. The test papers were then sent to 40 "outstanding teachers of science" who were asked to score the tests. Evaluated tests were received from 25 of these teachers, 15 of whom lived outside Wisconsin.

A fact-theory test of 103 statements was also constructed, of which these statements are typical: "A disease is a punishment for some particular moral wrong," "Air is composed of molecules," and "The pressure in water varies with the depth." The directions were to check each statement for one of the following answers:

A—if the statement is a well established fact which is always true

B—if the statement is a well established theory which is generally accepted

C—if the statement is a theory which is questioned by some (many) authorities

D—if the statement is a popular belief which is not supported by evidence

E—if the respondent is not familiar with the statement

This test was administered to the same 295 pupils to whom the earlier test on cause and effect relationship had been administered, and also to some teachers. The results were scored by the same 25 teachers who had scored the previous test.

"Tentative Conclusions."—1. "High-school pupils in Wisconsin are not superstitious."

2. "High-school pupils make almost as good records as the teachers."

3. "Many of the theories in science are being taught as facts by many of our best teachers. Teachers as well as pupils fail to distinguish clearly facts from theories."

4. "Pupils seem to have a fairly clear concept of the cause and effect relationship, but they do not seem to be able to recognize the adequacy of a supposed cause to produce the given result."

5. "Many teachers tend to propagandize their material when there is no specific evidence for the statements they make."

6. "Teachers do not consciously attempt to develop the characteristics of a scientific attitude. If pupils have acquired these characteristics, it has come about by some process of thinking or experiences outside of the science classroom."[1]

STUDY NO. 222

Measuring the Scientific Attitude

By Victor H. Noll*

Problem.—To construct and evaluate tests to measure the scientific attitude.

Method.—An examination of such works as Dewey's *How We Think*, and Karl Pearson's *Grammar of Science*, together

[1] The remainder of this article is devoted to a discussion of plans and progress toward further expanding, refining, and improving the tests of the characteristics of the scientific attitude; in suggesting further problems for investigation in connection with the scientific attitude; and in suggesting materials to be used in developing various phases of the attitude in the pupils.

* *The Journal of Abnormal and Social Psychology*, XXX (July–September, 1935), 145–154. A detailed report of the background of this study is presented serially, under the titles, "The Habit of Scientific Thinking," "Teaching the Habit of Scientific Thinking," and "Measuring Scientific Thinking," in *Teachers College Record*, XXV (October, 1933), 1–9; (December, 1933), 202–212; and (May, 1934), 685–693, respectively; the material is also published as a monograph, *The Habit of Scientific Thinking* (*A Handbook for Teachers*) (New York: Bureau of Publications, Teachers College, Columbia University, 1935).

with the investigator's consideration, led him to analyze the scientific attitude into the following "habits of thinking":

Habit of accuracy in all operations, including accuracy in calculation, observation, and report. The opposite of this habit is the habit of careless, inaccurate work.

Habit of intellectual honesty. Its opposites are habits of exaggeration and rationalization.

Habit of open-mindedness. The opposite of open-mindedness is bigotry, prejudice, and intolerance.

Habit of suspended judgment. Its opposite is the habit of making snap judgments, or of jumping to conclusions.

Habit of looking for true cause and effect relationships. Its opposites are habits of superstitious thinking, of expecting rewards to come without commensurate effort.

Habit of criticalness, including that of self-criticism. Its opposite is the habit of accepting explanations of phenomena without question, or without attempt at evaluation; the habit of condoning and accepting such things as racketeering, political corruption, and the like, as inevitable.

A large number of test items were devised that seemed to present situations which provided opportunities for the exercise of the respective habits as outlined. These items dealt for the most part with social rather than laboratory situations. Examples of these test items follow:

Intellectual Honesty.

(1) If the cashier in a store or other place of business gives me too much change, that is her lookout.

(2) I often get the blame for something I didn't do.

Open-mindedness.

(1) Evolution is something I do not care to know about.

(2) There can be no sure cure for cancer.

Suspended Judgment.

(1) Our next president will be a ( ) Democrat; ( ) Republican; ( ) Socialist; ( ) Farmer-labor; ( ) Communist; ( ) Can't tell.

Looking for True Cause and Effect Relationships.

(1) Tornadoes, earthquakes, and similar catastrophes are punishments for sin.

(2) People with red hair are usually ill-tempered.

Criticalness.

(1) One should always support the school or home team no matter what the circumstances may be.

(2) If one of my teachers says a thing is so, it must be so.

A mimeographed trial form of the test, including 134 items, was administered to 383 pupils, that is, to 28, 138, 86, 67, and 64 pupils respectively, in Grades VIII to XII inclusive in one school system. The means and S.D.'s of the scores were determined, as were also the critical ratios of the means to the respective S.E.'s of these differences, in order to determine whether the differences between the mean scores for the various grades were reliable. A reliability correlation of .80 was found by the method of chance halves and the application of the Spearman-Brown Formula; also a correlation of. 41 was computed between scores on this test and I.Q.'s.

A separate tabulation of the responses of 192 individuals to each of the 134 items of the test provided both the basis for obtaining the "difficulty value of each item," and evidence with respect to the validity of the items. Thus, the validity of the test was indicated by a comparison of "the responses to each item by the persons in the top 20 per cent of total scores with the responses to the same items made in the lowest 20 per cent of total scores."

A scoring key, "based upon the responses of a small group of experts in the fields of social science, natural science, and psychology," was prepared, and all items the answers to which were debatable were deleted.

"Following the trial and analysis of results of the first trial form, many items were discarded and new items as well as new types of item were devised. Four new trial forms were then constructed," which contained respectively 71, 79, 85, and 86 items, and which "were roughly comparable with respect to the types of items included." These forms were tried out with the pupils in a small junior-senior high school and the mean percentage score of each of the six classes was computed.

"The correlation of the I.Q.'s of these 140 pupils with the percentage scores on the test was .30." "Again a careful analysis was made of individual items, the relative difficulty and discriminatory value of each were determined, and the items which proved to be unsatisfactory in these respects were discarded. After careful comparisons and checking, the best remaining items were assembled into two forms of 112 items each, . . . comparable with respect to type, average discriminatory value, and relative difficulty of items."

Findings and Conclusions.—1. With the initial test the percentages of correct responses made by the 192 pupils varied from 10.9 to 97.4 per cent. This fact shows that "the range of difficulty was satisfactory, although a few more difficult items might be desirable."

2. The mean per cent scores on the four revised trial forms varied from 52 per cent for the seventh grade to 68 per cent for the twelfth. "The differences between successive grades are small but regular and fairly constant."

3. The correlation of .30 between the scores on the four revised trial forms of the test of scientific attitude and the I. Q.'s, which "is lower than that (.41) obtained with the first trial form, . . . indicates a still smaller relationship between intelligence and scores on this test." The test therefore measures "factors in the thinking of these pupils other than intelligence, or native ability."

4. With the original test, "the items designed to measure intellectual honesty had the highest average discriminatory value; the items designed to measure open-mindedness, and the habit of looking for true cause and effect relationships had the next highest average discriminatory values; the lowest average discriminatory values were obtained for those items designed to measure accuracy, suspended judgment, and criticalness, respectively." This is evidence of the validity of this test.

5. The critical ratios obtained with the original trial form revealed "reliable differences between eighth-, ninth-, and

tenth-grade means on the one hand, and eleventh- and twelfth-grade means on the other." These results indicated that "older children make higher scores and the greater the interval between the grades being compared, the more reliable the difference between their respective mean scores."

6. The steady decrease in variability of scores as shown by the S.D.'s (with the exception of the eighth grade) with the first test, "probably indicates that through maturation or instruction or both, the opinions of these pupils become more and more similar as the proportion of desirable responses increases."

STUDY NO. 223

Investigations of Scientific Thinking

By Elliot R. Downing*

UNIT I

Problem.—Do pupils acquire skill in scientific thinking as a by-product of the study of science?

Method.—The investigator administered his Test of Scientific Thinking[1] to "some twenty-five hundred pupils from the eighth to twelfth grades, inclusive." He then compared the average scores of all these pupils by grades, and of the Juniors and the Seniors of one of the schools by numbers of years' study of science. He also compared the scores of 15 pairs of these Juniors; the members of each pair had "the same or almost the same I.Q.'s," one had studied science two years, the other had studied no science. Also he compared the scores of 13 pairs of Seniors of another high school; the

* The first unit is reported under the title, "Does Science Teach Scientific Thinking?" in *Science Education*, XVII (April, 1933), 87–97; the second appears as "Some Results of a Test on Scientific Thinking," in *Science Education*, XX (October, 1936), 121–128.

[1] Elliot R. Downing, "Elements and Safeguards of Scientific Thinking," *The Scientific Monthly*, XXVI (May, 1928), 231–243.

members of each pair had the same C.I., one had studied no science, the other 3.5 to four years of science. He made comparisons of the scores of 200 Juniors; and also of 200 Seniors of this school on the basis of the number of years of science they had studied.

Findings.—1. "The returns show a gradual and fairly uniform increase in the percentage of correct answers from grade to grade."

2. With the paired groups of Juniors, "in nine cases out of the 15, the pupils with no science made higher scores than those who had had two years of science."

3. A comparison of the scores of the paired Seniors shows an average advantage (51.6 as compared with 50.5) in favor of those who had had no courses in science.

4. The large unpaired groups of both Juniors and Seniors who had not studied science made average scores on the test which were respectively .4 and 8.9 per cent greater than those of the corresponding groups of Juniors and Seniors who had studied from two to four years.

5. "If the scores [of the Juniors and Seniors combined] be grouped in three classes, high, medium, and low, we find that the 48 Juniors and Seniors with no science have a larger proportion in the A- (high) group than have Juniors and Seniors who have had one year of science, in every problem; a larger proportion in A-group on every problem but two than those with two years of science; and a larger proportion in A-group on five out of 15 problems than those with three to four years of science."

UNIT II

Problem.—To determine the implications revealed by administering the Test of Scientific Thinking to pupils of several grade levels.

Method.—The investigator's Test of Scientific Thinking was administered at midyear in science classes, to over a thousand students in each grade from VIII to XII, inclusive, in three

schools; and to college Freshmen in several schools. Computations were made of "the percentages of correct answers on each exercise for each school . . . together with the average for each question, the average on the whole test for each grade in each school, and the total average for each grade level . . ."

Findings.—1. ". . . the average total scores for the successive grades increase with considerable regularity from the eighth to the twelfth . . . When these same pupils are grouped by ages rather than by grades this fairly regular increase in the average scores disappears."

2. Widely different scores are "made by the pupils of the same grade level on the several exercises of the test, and the very different rate of improvement in their skill in the use of the several elements and safeguards as progress is made from the lower grades to the upper."

3. "The reliability of the test calculated on the basis of the score on odd and even questions" on more than six thousand papers is .993.

4. Correlations between I.Q.'s and scores on all or part of the Test of Scientific Thinking are mostly in the neighborhood of zero.

5. ". . . some exercises prove many times more difficult than others and . . . on some exercises the improvement from eighth grade to twelfth grade is great, on others, negligible or even negative."

Conclusions.—1. ". . . there is no evidence in the data given . . . that high-school pupils acquire skill in scientific thinking as a necessary by-product of the study of scientific subjects as at present taught."[1]

2. "It would appear from these results that ability to think scientifically is a complex of a number of component abilities and that these develop at varying rates and differently in different communities. What the factors are that cause these differences the present study does not reveal."

[1] See *Investigations in the Teaching of Science*, Vol. I, p. 116.

3. ". . . general intelligence as expressed by the I.Q. is something quite different from ability to handle either the elements or safeguards of scientific thinking (if these exercises test such ability) and . . . skill in the use of the elements of scientific thinking is not related to an awareness of the necessary safeguards, at least among high-school pupils in science classes."

STUDY NO. 22

Investigations of Unfounded Beliefs

By Otis W. Caldwell* and Gerhard E. Lundeen

UNIT I

Problem.—To determine the extent to which junior-high-school pupils are influenced by certain unfounded beliefs.[1]

Method.—A list of 100 superstitious beliefs, assembled as a test, was submitted to 415 ninth-grade pupils, 235 boys and 180 girls, in "a large city in one of the agricultural states," and to

* Unit I of this series of studies is reported in Chapter IX of *Do You Believe It?* (Doubleday, Doran and Company, Inc., 1934); Unit II appears under the title, "A Study of Unfounded Beliefs among High-school Seniors," in *Journal of Educational Research*, XXII (November, 1930), 257–273, with a supplementary report under the title, "Students' Attitudes Regarding Unfounded Beliefs," in *Science Education*, XV (May, 1931), 246–266; Unit III is reported in a monograph, *An Experimental Study of Superstitions and Other Unfounded Beliefs* (New York: Bureau of Publications, Teachers College, Columbia University, 1932); and Unit IV is presented as "Changing Unfounded Beliefs—a Unit in Biology," in *School Science and Mathematics*, XXXIII (April, 1933), 349–413. Especial attention is directed to the "Selected Bibliography Dealing with Superstitions and Closely Related Ideas" in the authors' book, *Do You Believe It?* (Garden City, New York: Doubleday, Doran and Company, 1934), 288–300.

[1] "Unfounded beliefs: all beliefs that have no scientific basis or support. The term here includes superstitions, those involving fear as well as other beliefs for which there is no adequate foundation."

276 ninth-grade pupils, 130 boys and 146 girls in "a large Atlantic coastal city." These directions accompanied the test:

> The statements that follow describe the ways in which some people believe or act. Read each statement and then consider whether you believe, or would act, that way yourself. If you believe, or would act, the same, write the letter *S* in the brackets at the left of the statement. *S* is for *same*. If you believe or would act differently, write the letter *D* in the brackets at the left of the statement. *D* is for *different*.

A sample of this test follows:

> [ ] 1. Tells his dream before breakfast, if he wants it to come true.
> [ ] 2. Is anxious lest the person who takes the last piece of bread from the bread plate will never be married.
> [ ] 3. Wouldn't be willing to give a knife to his friend as a gift, since a knife as a gift signifies future disagreements.

Computations were made of the percentage of the total group and of each group's acceptance of each unfounded belief and "the percentage of acceptance of each idea by both groups combined." Comparisons were made of the responses of the entire groups from both cities and of the responses of the boys and of the girls in each city, by dividing the differences in mean scores by the S.E.'s of these respective differences.

Findings.—1. Not a single item of the test "failed to receive an agreement mark by some pupils," though several items were marked *S* by less than 5 per cent of these junior-high-school pupils.

2. Several of the items were marked *S* by more than 50 per cent of these pupils.

3. On the average these pupils marked 21.8 ideas in agreement. "The average pupil of an Eastern high school marked 17.8 ideas in agreement while the average number of ideas marked in agreement by pupils of a Midwestern city was 24.7."

4. The results of the test indicated that the girls accepted a sufficiently larger mean number of items than the boys to constitute a statistically significant difference (the difference in

means divided by the S.E. of the difference in means was for the Eastern School -7.84 and for the Midwestern school -5.16.)

UNIT II

Problem.—To find "to what extent high-school seniors of various localities have heard of, believe in, and are influenced by certain types of unfounded beliefs."

Method.—Two hundred ideas were selected from "investigations and compilations regarding superstitions that were found to have a wide geographical distribution, and concerning which it seemed important to secure further information. A few of these ideas selected for study have partial foundation in fact." These 200 ideas were made into a questionnaire which was accompanied by these directions:

Please read each statement listed below. Under each statement are three divisions, namely: (a) Heard, (b) Believe, and (c) Influenced.

Explanations are made to show how one may check the blank, so as to record his responses to the statements.

Explanation for Division (*a*) *Heard.*—If you have heard of the statement or the idea it conveys, check the word "Yes," after (a) "Heard." If you have not heard of it, check the word "No."

Explanation for Division (*b*) *Believe.*—If you believe the statement is true, check the word "Yes" after (b) "Believe." If you do not believe in it, check the word "No."

Explanation for Division (*c*) *Influenced.*—If you practice or follow the statement, or if it affects or influences you in any way or manner, check the word "Yes" after (c) "Influenced." If the statement has no effect upon you whatever, check the word "No." The two following examples will help to make this more clear:

A boy in school had his choice between two lockers, one numbered 12 and the other 13 but he decided to take locker 12 because he would rather not have anything to do with the number 13. This boy was influenced by the number 13.

A girl broke a mirror before coming to school one morning. She was somewhat anxious and afraid because she thought that breaking a mirror meant bad luck, or perhaps that some terrible tragedy would happen in her family. This girl was influenced by the breaking of a mirror.

The students gave their ages and sex but were not required to sign their names to their reports.

The questionnaire was sent to 10 high schools, six of which (three in Kansas, and one each in Indiana, Kentucky, and Pennsylvania) were in rural towns having populations of from several hundred to ten thousand people, and four were in schools of large cities (New York, Chicago, and Minneapolis). Usable responses were secured from 526 Senior boys and 392 Senior girls; of these 918 students, 340 represented the rural towns and 578, the large cities. The questionnaire was also filled out and returned by "78 Freshmen from the Zoology Department of the University of Illinois; 96 graduate students from the Psychology Department of Teachers College, Columbia University; and 32 graduate and 58 undergraduate students of the Psychology Department of New York University." The average ages of the 108 men of these college groups was 23 years, and of the 156 women, 26 years. This group of 264 college students represented 22 states of the Union.

Statistical comparisons were made of differences with respect to the three divisions, "Heard," "Believe," and "Influenced," between the responses (1) of the high-school Seniors living in large cities and of those living in small towns; (2) of the boys and of the girls; (3) of the high-school pupils and of the college students; (4) of the high-school Seniors and of the college students. Similar statistical comparisons were also made between the responses of the high-school Seniors of large cities and of those of small towns with respect to whether they had "heard," had "believed," or had been "influenced" by the items representing the different types of ideas, as weather proverbs, signs of luck, visitors, misconceptions about health, misconceptions derived from astrology, phrenology, etc., misconceptions about natural phenomena, witchcraft, spiritualism, etc., and miscellaneous. The reliability of the difference in each case was determined by dividing the difference in means by the S.E. of this difference. An elaborate summary was also made of the

responses of the 918 high-school Seniors to each of the 200 ideas.

Coefficients of correlation by the Pearson Product-moment Method were made "between age and score on 'Heard,' 'Believed,' and 'Influenced' of high-school Seniors," and also of 120 of the graduate students; "between the prevalence of Seniors of large cities and small towns on 'Heard,' 'Believed,' and 'Influenced,'" and similarly "between the prevalence of college students and high-school Seniors" with respect to these same three responses. Finally, the most important ideas were selected on the basis of "having an average per cent or above in all three respects, namely, 'Heard,' 'Believed,' and 'Influenced.'"

Conclusions.—1. ". . . agencies, including education, which influence people, have not prevented or removed belief in signs and superstitions among students. That education and experience tend to reduce such beliefs may be inferred from the fact that older persons in college show less such belief than do high-school Seniors."

2. "Senior-high-school students on an average have heard of approximately one-half of the total number of ideas in this study. On an average they believe in, and are influenced by, approximately one-fifth of the ideas that they have heard."

3. "College students have heard of a slightly higher per cent of the total number of ideas than high-school Seniors. However, they believe in considerably less, and are influenced by a somewhat smaller number."

4. "Weather proverbs, misconceptions about natural phenomena and those derived from the pseudo-sciences as astrology, phrenology, etc., have a comparatively higher average per cent 'believed' and 'influenced' on the basis of those 'heard' than signs of luck, visitors, etc., witchcraft, 'spirits,' etc., and misconceptions about health."

5. "Among high-school Seniors, girls have heard, believe in, and are influenced by a greater number of unfounded beliefs

than are boys." "This is true both in rural communities and city communities."

6. "College women have heard, believe in, and are influenced by a greater number of unfounded beliefs than are college men."

7. "High-school Seniors of the smaller communities have heard, believe in, and are influenced by a greater number of unfounded beliefs than are high-school Seniors of large cities."

8. "The per cent 'influenced' on the basis 'heard' is greater among high-school students of small communities than among high-school students of large cities, but the average per cent 'believed' on the basis of 'heard' is practically identical for both groups of students."

9. "College students have heard of a greater number of unfounded beliefs, but believe in, and are influenced by them to a lesser degree."

10. Little or no correlation was found between student age and the extent to which he believed in or was influenced by the unfounded ideas.

11. "This study makes it clear that some thirty unfounded ideas are the most prevalent and most influential ones of the list of two hundred." These ideas, or items, follow:

THE THIRTY MOST IMPORTANT ITEMS OF UNFOUNDED OR NOT ADEQUATELY FOUNDED BELIEFS AS INDICATED BY THE RESPONSES OF TWO HUNDRED HIGH-SCHOOL SENIORS

Frost is frozen dew.

Snow is frozen rain.

If animals acquire an unusually heavy coat of fur, that fact foretells a severe winter.

Winters now are less severe than they were thirty or forty years ago.

You can make an accurate estimate of an individual's intelligence by looking in his face.

When squirrels gather an unusual supply of nuts, that fact indicates a severe winter.

When rheumatic people complain of more than ordinary pain in the joints, there will soon be rain.

A man's character may be judged by the features of his face.

If you stare at a person's back, you can make him turn around.

A circle around the moon is a sure sign of rain.

Long slender hands indicate an artistic nature.

Children who are especially intelligent are likely to be weak and retarded physically.

In the days of old, human life was much longer than it is today.

A person who does not look you in the eye is likely to be dishonest.

Any physical or mental disease can be produced by thinking too much about it.

Misfortunes never come singly.

A high forehead indicates superior intelligence.

A square jaw is a sign of strong will power.

During long periods of drought, individuals or groups of individuals by their prayers can cause it to rain.

Brains and beauty rarely go together.

If March comes in like a lamb, it goes out like a lion.

Fat people are always good natured.

Dew falls from the sky.

Some snakes charm birds and other animals, even human beings.

The general form and condition of the hand, the shape and markings on the fingers indicate fitness for social, intellectual, or practical work.

Red hair is a sign that the possessor has a violent temper.

Brunettes are more trustworthy than are blondes.

A snake's tail will not die until sun-down.

If you find a four-leafed clover it will bring you good luck.

If the ground-hog sees his shadow on ground-hog day (February 2), there will be six weeks of bad weather.

UNIT III

Problem.—"To determine whether desired attitudes may be developed by direct and specific instruction regarding common beliefs, that have little or no basis in facts."

Method.—The investigators selected for remedial instruction unfounded beliefs which included misconceptions and superstitions.[1] They next prepared for use in classes of general science in junior high schools, three teaching units constructed so as to contain "discussions of common erroneous ideas . . .

[1] "Misconceptions and superstitions are alike in that they do not have scientific support. A superstition also involves an element of fear."

as parts of subject matter." These three units, thus prepared, were presented:

Unit I. Some Personal Problems
Part A. Problems Related to Health
Part B. Individual Problems
Unit II. The Earth and Other Heavenly Bodies
Unit III. Weather Conditions

Each unit began with a short introductory paragraph which was followed by a series of problems, as "What are bacteria?" "Are dependent organisms beneficial?" and the like. Each problem was followed by references to standard textbooks of general science; also by short-answer tests or by supplementary instructional material giving pertinent facts and valid reasons for belief or disbelief, or by both.

During the spring of 1931 and the academic year of 1932–33, three experiments were conducted with these units. In the first, 839 pupils of 26 classes in nine states devoted an average of 15.7 hours to Unit I; in the second, 472 pupils of 18 classes in nine states devoted an average of 14.9 hours to Unit II; and in the third, 488 pupils in 25 classes in four states, devoted an average of 10.9 hours to the study of Unit III. "The three experiments include usable reports from 1,799 pupils involving 69 general science classes, 29 high schools, and 15 states of the Union . . ."

"The methods of instruction varied considerably. Some teachers used definite daily assignments which were followed by class discussions, the more capable pupils being given additional work from time to time. Other teachers used individualized instruction, each pupil proceeding at his own rate, and additional assignments were given to those pupils who were able to complete the unit in less time than the average pupil. A combination of these methods just mentioned was used by some of the teachers. A few teachers did not make any special teaching effort; the pupils simply worked on the units outside of school hours."

True-false tests of respectively 50, 52, and 48 items were given at the beginnings and at the ends of Experiments I, II, and III; a multiple-response form of 50 items, involving the same ideas as those incorporated in the true-false test, was also given at the end of Unit I; and similar tests of respectively 52 and 48 items were given at the beginnings and at the ends of Units II and III.

The results of each experiment were considered (1) with respect to the changes in attitudes toward certain unfounded beliefs, of the group as a whole; of the younger pupils as compared with those of the older pupils; and of the boys as compared with those of the girls; (2) with respect to "pupil achievement with reference to the objectives of the units as a whole"; (3) with respect to the responses of the pupils to each individual test item at the beginning and at the end of the instruction. In order to determine the significance of the results with the boys as compared with those with the girls, the difference of the means was divided by the standard error of this difference.

Findings and Conclusions.—1. "The average per cent gain in desirable responses after a period of instruction was greater with reference to unfounded beliefs than it was for the factual elements included in the units."

2. "In each of the three experiments the final test shows a gain for each item dealing with unfounded beliefs."

3. "The individual items showing the highest per cent gain after instruction in each experiment were those that related to unfounded beliefs."

4. "Belief among young people in unfounded ideas used in this study seems to be largely due to lack of correct information."

5. ". . . a change of attitude in regard to the unfounded beliefs included in the units may be produced by direct and specific instruction."

6. "In order to make remedial instruction in regard to unfounded beliefs effective, specific instruction regarding facts related to such beliefs is necessary."

7. "Younger pupils received higher scores in desirable responses regarding unfounded beliefs in both initial and final tests for each experiment than did the older pupils; also, a greater per cent gain. This indicates a negative correlation between intelligence and belief in superstitions and other unfounded beliefs."

8. "The younger pupils made higher achievement records with reference to factual elements and major understandings (unfounded beliefs included) than did the older pupils . . ."

9. "The co-operativeex periments with the units have provided evidence by means of which to improve the clarity both of statement of problems and subject-matter discussions; also, valuable information for revising and improving the tests."

10. "It has been proved impossible to incorporate specific instruction in regular curricular units by means of which to produce an effect upon unfounded beliefs."

UNIT IV

Problem.—To measure "the effects of specific instruction regarding certain unfounded beliefs that are associated with the subject of heredity."

Method.—The technique used in this investigation was similar to that employed in the previous one. Materials were prepared on eight unfounded beliefs included in the investigators' biological unit, *Heredity and Its Applications*. This unit was experimentally used in two Pennsylvania high schools, in the first with 173 Sophomore boys in seven classes under seven teachers, and in the other, with 19 boys and 39 girls, all Seniors, in two classes under one teacher. "The

average age of the Sophomore boys was 16 years and of the Senior boys and girls 18 years. These Seniors had all studied biology previously.

"A test consisting . . . of . . . 35 true-false statements and 35 statements of the multiple-choice type was given before and after instruction. The two parts of the test involved identical items. Eight items in each part of the test involved unfounded beliefs. The other items dealt with concepts usually included in a unit dealing with the subject of heredity. The scores which the pupils made on the test were determined by combining the scores of the two parts; that is, the correct responses minus the incorrect responses of the true-false part were added to the number of correct responses of the multiple-choice part." The mean gains and the percentage gains of the Sophomore boys and the Senior boys and girls were compared, as were also the mean and the percentage gains of the nine participating classes, with respect to both the items dealing with unfounded beliefs and those dealing with factual elements.

Findings and Conclusions.—1. "The unfounded ideas considered in this report were shown by previous studies to be widespread."

2. "The results of this study show that the knowledge foundations for desirable attitudes concerning certain facts may be developed by remedial instruction."

3. "As a result of instruction the average per cent gained in desired responses was greater regarding the unfounded beliefs than for all the items of the test. The average pupil gained 32.9 per cent in desirable responses regarding the unfounded beliefs and 23.1 per cent regarding the factual elements including the special items dealing with unfounded beliefs."

4. "The average Senior possessed the knowledge foundations for more desirable attitudes regarding the unfounded ideas previous to instruction than did the average Sophomore boy."

5. "Senior-high-school pupils made higher average scores on the initial and final tests regarding both the unfounded ideas and factual elements of the unit. The Sophomore boys made a greater average gain in desirable responses concerning the unfounded beliefs after a period of instruction, while the Seniors made a slightly greater gain on the entire test."

6. "Discussions of common unfounded beliefs included in this study may serve as a basis for motivation of pupil's interest in the subject of heredity and may serve as useful material in teaching scientific attitudes."

7. "This study gives no evidence regarding whether the gains in desirable attitudes will persist. It seems reasonable to suppose that their persistence may be no less than knowledge of the facts involved."

STUDY NO. 225

Attitudes and Skills in Elementary Science

By Florence Weller*

UNIT I

Problem.—To determine some of the attitudes and skills which can be developed in elementary science.

Method.—"In two units of study for sixth grades, one on *Our Universe*, and the other on *The Adaptability of Plants and Animals to Their Environment*, an attempt was made to direct both teachers' and children's attention to attitudes as well as factual knowledge." Two true-false tests on each unit were constructed. The first half of each test was composed of items testing scientific attitudes and the second half items testing factual information. The reliability and validity of the first test of attitudes were computed and considered by the investigator to be sufficiently high; the second test was assumed to be equally reliable and valid since "it was based

* *Science Education*, XVII (April, 1933), 90–97.

on the same criteria" as the first test, and was "planned in a similar way."

These tests were administered to 450 children in 11 sixth-grade classes in Baltimore schools, one before instruction in the two units had begun and the other when both units had been completed. Percentage gains were computed for each of the classes on both pairs of tests.

Findings.—"The results show that equal gains have been made in the learning of attitudes items and of knowledge items, that is, so far as paper and pencil methods go in testing these facts."

UNIT II

Problem.—To determine whether "desirable attitudes and skills in problem solving," and some elimination of superstition can be effected in elementary-school pupils through instructional procedures.

Method.—Three pairs of tests were constructed: Each test of the first pair, (Tests I-A and II-A) consisted of 45 true-false items "each based on superstitions and erroneous conceptions connected with the topic"; each test of the second pair (Tests I-T and II-T) consisted of 21 multiple-response items "constructed so that the first question of each set attempted to measure observation, the second a conclusion drawn, and the third a proof or possible verification of the conclusions drawn"; each test of the third pair (Tests I-K and II-K) consisted of a "true-false examination of 17 items each testing factual knowledge only." Each of the two sets of three tests covered the same units as did the two sets of two tests used in the preceding investigational unit. The reliability of Test I (formed by combining Tests I-A, I-T, and I-K) was found to be .89; Test II (similarly formed by combining Tests II-A, II-T, and II-K), was assumed to be equally reliable "since it was planned in the same manner [as Test I] and used items of about the same difficulty [as those of Test I]."

Six sixth-grade classes enrolling 230 children in Baltimore schools were taught the two units of subject matter. "In three of the classes [which together constituted the experimental (X-) group], the attitudes and techniques were stressed. Erroneous conceptions were deliberately brought up and discussed and superstitions argued about.[1] One method of scientific thinking, that is, observation of much data, drawing a conclusion from it, and attempting to verify this conclusion, was practised, using simple problems of the children. In the other three classes [which together constituted the control (C-) group], only factual items were discussed. If a question were asked involving other than factual information it was answered correctly but no attempt was made to continue the discussion."

Both tests were administered to both groups after the two units of subject matter had been completed. The scores of 30 members of the X-group were compared with those of 30 members of the C-group on the three separate parts of the two tests, the parts respectively on scientific attitudes (Tests I-A and II-A), on techniques of scientific thinking (Tests I-T and II-T), and on factual knowledge (Tests I-K and II-K). These two groups were equated on the bases of I.Q.'s, M.A.'s, C.A.'s, and scores on Stanford Reading Tests. A further comparison was made of the scores of these two groups on each of the three tests (Tests A, T, and K) made by combining the corresponding sections of the two tests. A final comparison was made of the scores on Tests A, T, and K, of all the children (180) of the two original X- and C-groups, whose scores were available.

The significance of the results was determined from the critical ratios (difference in mean scores of the X- and C-groups on each part of the tests, divided by the S.D. of the difference in these mean scores).

[1] Compare with study by Curtis, *Investigations in the Teaching of Science* Vol. 1, pp. 112–116.

Findings.—1. The critical ratios obtained in the first comparison from the scores of the equated group on the six parts of the two tests indicate statistically significant results favoring the X-group on all parts except Tests I-K and II-K. The latter show statistically significant results in favor of the C-group.

2. The critical ratios computed from the scores of the equated groups on Tests A, T, and K, show statistically significant results in favor of the X-group for the attitudes and techniques (Tests A and T) and in favor of the C-group for factual knowledge (Test K).

3. The comparisons for the large group on Tests A, T, and K show statistically significant results in favor of the X-group for all three factors.

Conclusion.—"It seems reasonable to conclude that the teaching of elementary science with proper guidance, provided an opportunity to grow in other ways than in the accumulating of factual material; that the material of elementary science provides the means of developing desirable attitudes and skills in problem solving, if attention is focused on this aim; and that some beginning has been made in determining the effects of instruction upon superstitious beliefs associated with the phenomena that are studied."

STUDY NO. 226

Sources of Superstitious Beliefs

By Julius B. Maller* and Gerhard E. Lundeen

Problem.—To "study the individual sources of superstitious beliefs, the social and educational factors that contribute toward the learning and unlearning of unfounded ideas."

Method.—Following a careful survey of the investigational literature dealing with studies of superstition, a selection was

* *Journal of Educational Research*, XXVI (January, 1933), 321–343.

made of 50 items dealing with unfounded beliefs of considerable prevalence. Most of these were superstitions, such as, "Friday the thirteenth is a very unlucky day," or "If you drop a knife or spoon you may expect company," but a few were common misconceptions, as, "If you stare at a person's back you can make him turn around and look at you." In this study, however, all such misconceptions were classed as superstitions.

The items were made into a questionnaire of this form:

	Home	School	Church	Friends	Books	Newspapers	Observation
( ) The stars are small objects....							
( ) Seven is a lucky number...							

The individual responding to the questionnaire was asked to write "+", "−", or "?" in the parentheses in front of each item to indicate respectively that he thought the item was true, that he thought it was false, or that he was uncertain as to its truth or falsity. He was also asked to write "T" or "F" opposite the item and under the name of each agency (home, school, church, etc.) from which he had learned about the item, to designate whether the agency supplying the information concerning the item had represented it as true or false. He was also asked to state which of 10 types of books (adventure, biography, history, mystery stories, fiction, economics, travel, invention, science, and fairy tales) he liked best to read.

Responses to the questionnaire were obtained from 113 boys and girls of a junior high school in East St. Louis and 66 boys of the Western Union Continuation School in New York City. The average age of the members of the former group was 13, and of those of the latter group, 16 years. The results were

analyzed for the prevalence of superstition among these boys and girls by computing the "average and variability of the number of superstitions marked true, false, and uncertain" by the older boys, by the boys and the girls of the junior high school, and by all these groups combined. Reliabilities of the differences between the responses of the boys and of the girls were determined by dividing the differences in means by the S.E.'s of these differences. Coefficients of correlation were computed for the combined groups, between age and the number of superstitions marked true. Determinations were likewise made of the average number of superstitions related to each source for the group as a whole, for the younger boys as compared with the older boys, and for the junior-high-school boys as compared with the junior-high-school girls.

Two further analyses were made of the responses of 100 of the junior-high-school group to the individual items. In the first, the results concerning the sources of the superstitions were studied to determine "the relative contribution of each source toward the acquisition and the elimination of superstitious beliefs." In the second, an item by item analysis was made to determine "what specific items of superstition were related to each of the sources"; this objective was accomplished by "finding the numbers of these boys and girls who had learned that each item was true or was false," from each of the seven agencies.

"Corrective Indexes"[1] were computed in each of these various cases.

A final determination was made of the relationship between the type of reading preferred and the belief in superstition, for those who preferred to read science books and those who preferred to read fiction books. The significance of the

[1] "The Corrective Index is the ratio of the number heard as false to the number heard as true. The higher this ratio, the greater the corrective influence of the source."

results of this comparison was determined by dividing the difference in mean scores of belief by the S.E. of this difference.

Findings and Conclusions.—1. "The average pupil expressed a belief in 30 per cent of the items, a disbelief in 55 per cent, and uncertainty about 15 per cent of the items."

2. "Young pupils were found to believe in a greater number of items than the older ones. The correlation between belief and age was $-.23 \pm .05$."

3. "Girls expressed belief in a greater number of superstitions than boys. The difference in terms of its standard deviation was 3.0."

4. "The source that ranked first in order of fostering superstition was that of friends. This source ranked last in order of correcting superstitions. Next in order was the home, while the educational sources [books, newspapers, school, and church] and observation were found to contribute least to belief in superstitions."

5. "The order of the sources, in correcting superstitions was: observation, educational [church, school, newspapers, and books], home, friends."

6. "The Corrective Index of each of the sources was higher among the boys than among the girls."

7. "Among younger pupils the Corrective Index was lower than among the older ones as far as friends, home, and observation were concerned. The Corrective Index of the educational source was slightly higher among the younger pupils."

8. "There is a relation between the extent of belief in superstition and the nature of information received from the various sources. The correlation between the number of an individual's beliefs and the Corrective Index of the sources of his information was $-.25 \pm .05$."

9. "There is some relationship between the number of superstitious beliefs and the type of reading preference. Those preferring books of science and invention expressed less

belief in superstition than those preferring books of fiction, adventure, and mystery."

10. "The results indicate that the effectiveness of each of the sources, whether it is in the direction of fostering superstition or correcting superstitions depends upon the total background of the individual. The same source may be fostering superstition in one individual and correcting superstitions in another."

STUDY NO. 227

Health Misconceptions of Seventh-, Tenth-, and Twelfth-grade Students

By E. Benton Salt*

Problem.—"To ascertain the relative prevalence of certain health misconceptions[1] and superstitions as subscribed to by students in the seventh, tenth, and twelfth grades of Florida public schools; to make pertinent comparisons on the basis of sex, grade, race, type of home community, [and] geographical location; and to discover whether there is any relationship between health knowledge and socio-economic status on the one hand and belief in health misconceptions on the other."

Method.—A preliminary Health-information Test of 300 true-false items was constructed from materials secured from

* Unpublished dissertation for the degree of Doctor of Education, New York University, 1936.

[1] Misconceptions and superstitions may properly be designated as unfounded beliefs, a category which "includes all beliefs or ideas that have no scientific basis or support by facts," and that are "further characterized" by having "a causal relationship . . . implied between objects, phenomena, or events where such relationship does not exist." "Misconceptions and superstitions are alike in that they lack scientific support; however, a misconception arises as the result of misinformation, the lack of information, or even unsuccessful attempts to arrive at a rational explanation." A superstition may be considered to embody "an element of fear, faith, or the supernatural."

five sources: (1) "earlier studies of folk-lore, unfounded beliefs, health misconceptions and superstitions"; (2) "books, articles, and compilations dealing with folk-lore, popular errors, healing magic, omens, nostrums, faith healing, superstitions, medical delusions, misconceptions, and pseudo-medicine"; (3) "press, magazine, radio, and other forms of advertising which contained unfounded health ideas, either stated or implied"; (4) "a list of health misconceptions and superstitions compiled by certain public health nurses in Florida"; and (5) "contributions from various students, teachers, and doctors." This preliminary test was administered in the fall of 1935 to a representative group of 653 pupils of the seventh, tenth, and twelfth grades in public schools of Florida. It was submitted, also, to six physicians, who validated the test items and commented upon such statements as they thought were debatable or ambiguous.

For the final test, 118 false and 32 true items were selected. In the process of selecting these items, all statements in the preliminary test marked correctly by 95 per cent or more, and all marked incorrectly by 95 per cent or more of the trial test group were eliminated. Certain other items were also eliminated because they presented vocabulary difficulty or because of other reasons. One hundred fifty items were retained as valuable items in accordance with the criterion that "a very valuable item is one that is passed only by those whose total scores are considerably higher than the total scores of those who fail that same item."

The 150 items of the final test were grouped in these subject-matter divisions: "Mental Health," "Oral Hygiene," "Food and Nutrition," "Physical Activity," "Organic Function and Disturbance," "Contagions and Infections," "Preventive Measures," "Remedial Measures," "Safety and First Aid," "Advertised Products," and "Miscellaneous Health Misconceptions."

A sample of the test items together with the summary of correct responses to these items is shown in Table LXXXXIII.

"A questionnaire was provided at the beginning of the test to collect data pertaining to the student's name, age, sex, race, grade, home community, and [the] location of the school." A letter was sent to 52 principals of junior-senior high schools in all parts of Florida inviting their co-operation. Thirty-two of these principals signified their willingness to help.

TABLE LXXXXIII

HEALTH INFORMATION TEST ITEMS RANKED IN DESCENDING ORDER ACCORDING TO THE PERCENTAGE OF NINE HUNDRED EIGHTY-NINE SEVENTH-GRADE WHITE STUDENTS MARKING EACH ITEM INCORRECTLY

Rank	Item	Correct response	Per cent responding incorrectly
1	Everyone should engage in deep-breathing exercises daily	F	92
2	Returning canned food to the refrigerator in its original container after it has been partly used will cause tin or lead poisoning.	F	89
3	Milk contains all of the essential elements of a good diet and in sufficient quantities to insure good health and normal body development	F	88
4	It is more dangerous to prick one's self with a pin than with a needle	F	86

Responses to the test were accordingly secured from 3,221 pupils in the seventh, tenth and twelfth grades in 26 schools for white pupils, and from 592 pupils of these same grades in six schools for Negro children. To determine whether the white pupils responding constituted a representative sampling, the responses of the seventh-, tenth-, and twelfth-grade pupils in two groups of respectively 1,022 and 997 pupils selected at random, were compared with respect to their critical ratios (differences in means divided by S.E.'s of these respective differences). The resulting quotients were all less than 3.0;

hence the pupils in each grade were assumed to be representative. The reliability of the test computed by the Pearson Product-moment Method and corrected by the Spearman-Brown Prophesy Formula from the responses to odd and even items in a random sampling of 1,009 tests, was found to be .903.

The test scores were compared statistically, on the basis of 37 categories which included grade, sex, type of home community, geographical location, and race.

"To ascertain the relationship between the socio-economic status of a student and the degree to which the student subscribes to certain health misconceptions, the scores made by 638 white students on the Sims Score Card for Socio-economic Status were correlated with scores made by the same students on the Health Information Test." A similar computation was made between the scores of these students on the Sims test and on the Gates-Strang Health-knowledge Test, Form I. The basis for each of these comparisons was obtained from a computation of the critical ratio determined by dividing the difference in means by the S.E. of this difference.

Conclusions.—1. "Unfounded beliefs relating to health are found to be quite prevalent among seventh-, tenth, and twelfth-grade students in the public schools of Florida, and it appears that formal education has failed in a marked degree to eliminate certain health misconceptions from the beliefs of students in these grades."

2. "The tenth-grade white students subscribe to certain health misconceptions in a greater degree than do the twelfth-grade white students," and to a much smaller degree than do the seventh-grade students.

3. "White girls in the seventh, tenth, and twelfth grades subscribe to certain health misconceptions in a greater degree than do white boys in the same grades of Florida public schools."

4. The reactions with respect to certain health misconceptions were approximately the same for seventh-, tenth-, and twelfth-grade students living in rural and in urban communi-

ties, and for white students of these three grades living in East Florida and in West Florida.

5. "Seventh-, tenth-, and twelfth-grade Negro students in the public schools of Florida subscribe to certain health misconceptions in a much greater degree than do white students of the same grades."

6. "There is no one type of health misconception characteristic of any seventh-, tenth-, or twelfth-grade group, i.e., boys, girls; urban, rural; East Florida, West Florida; white or Negro groups." Misconceptions relative to "Physical Activity" and "Advertised Products," however, rank consistently first and second in order of prevalence, and those relative to "Contagions and Infections" and to "Mental Health" have consistently the last two ranks.

7. There is "very little relationship between the factual health knowledge" which a white student of the seventh, tenth, and twelfth grade possesses, and "the degree to which the boy or girl subscribes to certain health misconceptions."

8. "In the case of seventh-, tenth-, and twelfth-grade white students, the relationship between the socio-economic status of the student and the degree to which the boy or girl subscribes to certain health misconceptions, is found to be negligible."

STUDY NO. 228

Correlation of Natural-science Beliefs and Attitudes with Social and Intellectual Factors

By J. Wayne Wrightstone*

Problem.—To determine the degree of correlation existing between pupils' beliefs relating to natural science, and such social factors as verbal intelligence, knowledges in general science, and socio-economic status.

* *Science Education*, XVII (February, 1934), 10–12.

Method.—The investigator constructed a test of which Part I consisted of 28 true generalizations comprising such generalized beliefs, or concepts, as, "The earth is very old," and "The earth is shaped approximately like a sphere";[1] and 52 false generalizations or superstitions that were found to have the highest incidence of belief among secondary school pupils.[2] Part II, on scientific thinking, consisted of 10 problems on natural science context with certain multiple conclusions stated. "The coefficient of reliability for split halves of the test was .88. When this coefficient was corrected by the Spearman-Brown Formula for the reliability of the total test, the coefficient was .93."

This test, together with the Otil Self-administering Test, the Co-operative General Science Test, Form 1933, and an adaptation of the Sims Score Card for Socio-economic Status was administered to pupils in Grades VII to XII, inclusive, in the secondary schools of Summit, New Jersey, and of Bronxville and Rochester, New York. Coefficients of correlation were computed between the scores on the investigator's test and (1) verbal intelligence as measured by the Otis Test, (2) knowledge of natural science as measured by the Co-operative Test, and (3) socio-economic status as measured by the Sims Score Card. Also the significance of the results for the scores of the boys and the girls on the author's test was determined by dividing the difference in mean scores by the S.D. of this difference.

Findings.—1. "Verbal intelligence . . . shows a positive, though low, correlation . . . with scores on natural science beliefs."

2. "Natural science knowledges . . . shows a positive correlation . . . with capacity to choose proved generalizations *versus* unfounded beliefs in natural science."

[1] See study by Craig, *Investigations in the Teaching of Science*, Vol. II, pp. 41–47.

[2] See study by Caldwell and Lundeen, pp. 280–291 of this volume.

3. "Socio-economic status reveals negligible correlation with natural science beliefs of secondary-school pupils."

4. "Statistically significant differences in average, or mean, scores for boys and girls . . . indicate that girls as a group are less discriminating in their science beliefs than boys."

STUDY NO. 229

Investigations of Retention

By Ralph W. Tyler*

UNIT I

Problem.—To determine the relative retention by pupils of factual knowledge, ability to explain everyday happenings, and ability to generalize from facts.

Method.—A battery of three tests was given in September and again in May by two teachers of general science in two high schools in Columbus County, North Carolina, to 68 of their ninth-grade pupils who had completed the course in general science in the preceding May. These tests were the Ruch-Popenoe General Science Test, Form A, and two new tests, one requiring explanations of commonly observed phenomena, and the other requiring generalization from given facts. Each of the 50 items of the explanations test "consisted of a statement of a commonly observed scientific phenomenon followed by five alternative explanations, the best one of which was to be checked." Each item of the test on generalizations "consisted of a brief description of an experiment. The results obtained from the experiment were given, followed by five alternative inferences which might be drawn from these

* Unit I is published under the title, "What High-school Pupils Forget," in *Educational Research Bulletin*, Ohio State University, IX (November 19, 1930), 490–492; Unit II is reported as "Permanence of Learning," in *Journal of Higher Education*, IV (April, 1933), 203–204.

results. The pupils were asked to check the inference which was most reasonable from the facts as given and the one least likely to be true." The reliabilities of these two tests were respectively .89 and .91.

Findings.—"It seems apparent [from Table LXXXXIV] that for these pupils the greatest loss during the year was in information about science,[1] whereas there was little or no loss

[1] Further evidence with respect to retention of factual knowledge is supplied by reports of two extensive investigations at the University of Minnesota. In the first study, Johnson* administered an informational test consisting of 126 true-false statements and 172 completion items to three groups of students at intervals of three, 15, and 27 months, respectively, following their completion of a course in elementary botany. The test results showed the following median percentage losses: 46.1 per cent after three months; 74.1 per cent after 15 months; and 76.1 per cent after 27 months. "The rate of loss would, therefore, appear to be quite rapid during the three and 15 months after completing the course, followed by a gradual decline afterwards." Further analysis of the data led to the conclusion by the investigator that "the students who have the most botanical information (as measured by the botany test)" at the time of completing the course in general botany, "are likely to retain not only absolutely but relatively more of this information after the lapse of six or three months in time."

In the second study Cederstrom† administered a test consisting of two range-of-information scales measuring factual knowledge of zoology, to one zoology class on the first day of the semester and to another group at the end of the first sixth of the course. He again administered the tests to both groups at the end of the course and also one year later. On the bases that "the gains are the difference between the scores in the initial and the final measurements"; and that "the retention scores are the differences between the initial scores and the scores made by the same students a year later," the investigator arrived at the following findings and conclusions: ". . . after the lapse of a year students retain approxi-

* Palmer O. Johnson, "The Permanence of Learning in Elementary Botany," *The Journal of Educational Psychology*, XXI (January, 1930), 37–47.

† J. A. Cederstrom, "Retention of Information Gained in Courses in College Zoology," *The Pedagogical Seminary and Journal of Genetic Psychology*, XXXVIII (December, 1930), 516–517.

in the ability to explain everyday phenomena and the ability to generalize from given facts."

TABLE LXXXXIV

AVERAGE TEST SCORES FOUR MONTHS AND ONE YEAR AFTER THE COMPLETION OF THE COURSE IN GENERAL SCIENCE

Test	Number of pupils	Mean score in September	Mean score in May	Mean loss in eight months	P.E. of mean loss
Ruch-Popenoe	68	27.9	16.8	11.1	1.7
Explanations	68	23.4	21.6	1.8	1.1
Generalizations	68	21.7	20.5	1.2	.9

UNIT II

Problem.—To determine the relative permanence of learning with respect to several types of materials in zoology.

Method.—This investigation involved 82 students who studied elementary zoology at Ohio State University during the year 1930–31, and who, "both with reference to average marks and spread, were typical of those enrolled in the elementary zoology course." In June, 1932, following a period of 15 months during which these students had taken no course in zoology, they were given a retest measuring several types of outcomes from the course. A comparison was made of the test scores of these students at the beginning of the course, at the time of the final examination, and again in 1932. Computations were made of the percentages of the gains made in the course which were lost by June, 1932.

mately .6 to .8 of the gain made during the course." "The selection or motivation of the women in the two groups tends toward better retention than that of the men." "Percentages of retention seem to be but slightly related to percentile ratings on college-aptitude tests, while the amounts retained seem related to the ratings on the college-aptitude test only to a small extent; percentages of retention have but little relation to the amounts of gain but the amounts of retention are proportional to gain."

Conclusions.—The data in Table LXXXXV indicate that ". . . specific information, which is represented by exercises requiring the naming of animal structures, is most quickly forgotten; that information of more general application is more permanent; and that during the 15-month period there was no loss in the ability of students to apply important zoological principles to new situations, or to interpret data obtained from experiments. If these results are substantiated

TABLE LXXXXV

THE RELATIVE RETENTION OF VARIOUS MATERIALS PRESENTED IN A COLLEGE COURSE IN ELEMENTARY ZOOLOGY

Types of examination exercises	Mean score at			Percentages of the gain made in the course which was lost by June, 1932
	Beginning of course, fall, 1930	Time of course examinations, June, 1931	June 1932	
Naming animal structures pictured in diagrams.	22	62	31	77
Identifying technical terms	20	83	67	26
Recalling information				
Structures performing functions in type forms.....	13	39	34	21
Other facts.....	21	63	54	21
Applying principles to new situations.....	35	65	65	*.07**
Interpreting new experiments.....	30	57	65	*25**

* The percentages set in italics are permanent gains.

by further investigations, it is clear that the permanent results of the college education are not the specific items of information recalled, and that the organization of courses and the development of examinations should center around those

objectives which are found to have more permanent value in college education."

STUDY NO. 230

Retention in High-school Chemistry

By F. P. Frutchey*

Problem.—To determine the extent to which pupils retain certain knowledges, skills, and abilities gained from the study of high-school chemistry.

Method.—During the summer of 1934, one teacher of chemistry in each of three high schools, the West and the Chardon High School of Columbus, and the Chillicothe High School, co-operated in this study, pooling their data. "The five objectives of high-school chemistry chosen for investigation were: the selection of chemical facts; the application of chemical facts and principles; a knowledge of chemical terms; a knowledge of symbols, formulas, and valence; and the balancing of equations. Each of these objectives was defined in terms of the behavior of pupils, and tests were prepared to get evidence of each type of behavior. The test of selection of facts consisted of a list of facts, general ideas, and misconceptions about topics in chemistry. The pupils were expected to select those which are true about each topic. The test of the application of facts and principles consisted of problem situations; the pupils predicted probable answers of these problems and indicated the facts and principles of chemistry supporting their judgments. A knowledge of terminology meant that the pupils could identify the chemical terms for each definition and description provided in a list. A test was prepared requiring this sort of behavior. Evidence of a knowledge of symbols, formulas, and valence was obtained by asking the pupils to

* *Educational Research Bulletin*, Ohio State University, XVI (February 17, 1937), 34–37.

write the names of elements for their symbols, the names of compounds for their formulas, and the valences of chemical elements in compounds. The fifth test consisted of unbalanced chemical equations to be balanced by indicating the number of molecules of each substance needed."[1]

TABLE LXXXXVI

RETENTION IN PERCENTAGE OF GAIN MADE DURING THE COURSE

Objective	Girls (22–36)*	Boys (45–62)	Boys and girls (67–98)
Selection of facts	64	93	84
Application of principles	93	91	92
Terminology	46	75	66
Symbols, formulas, and valence	65	73	70
Balancing equations	76	70	72
Total	67	87	81

* The number of pupils varies with the objectives; not all the pupils took the tests.

Table LXXXXVI is read thus: One year after the completion of their course in high-school chemistry, the girls remembered 64 per cent, the boys 93 per cent, and the boys and girls together, 84 per cent of the factual information they had gained during the course; etc.

These five tests were administered as pre-tests when the pupils as Juniors were beginning their study of chemistry. Nine months later, in May, 1935, at the close of the year, the pupils were again given each of the tests in order to determine the gains made during the course. In May, 1936, one year after the pupils had completed their high-school chemistry course, the tests were given a third time to serve as a basis for determining the loss or gain during the year. "The amount of retention was the difference between the pre-test results and the retention-test results." The amount of retention was

[1] For specific illustrations of these types of tests see F. P. Frutchey, "Retention in High-school Chemistry," *Educational Research Bulletin*, XVI (February, 1937), 34–37.

divided by the amount of gain indicated at the end of the course to obtain the "retention in percentage of gain."

Findings.—Table LXXXXVI shows the results of the investigation.

Conclusions.—"The difference in retention between boys and girls was quite marked in some objectives. In the selection of facts, terminology, symbols, formulas, and valence the girls lost their progress more rapidly than the boys. In balancing chemical equations the boys lost their progress somewhat more rapidly than the girls. In one objective both boys and girls retained about the same percentage of their progress. It is interesting to note that this latter objective is the application of facts and principles, a more general type of behavior. It was in this objective, too, that the largest percentage was retained." ". . . retention was greatest in the more general types of behavior. Although there were sex differences in the retention of achievement in some objectives, in the application of facts and principles, a more general type of behavior, there were practically no sex differences in retention."

STUDY NO. 231

Twin Examination Assumptions

By James E. Wert*

Problem.—To determine the relative retention of certain knowledges, skills, and abilities by university students of elementary zoology, who "later elected no further courses in that area."

Method.—During the school year 1930–31, six examinations were administered, both as pre-tests and final examinations, to all students studying elementary zoology in Ohio State University. Four of these examinations measured,

* *Journal of Higher Education*, VIII (March, 1937), 136–140.

respectively, knowledge required in naming animal structures, knowledge required in stating functions of structures, knowledge of terminology, and knowledge of other facts. The remaining two measured respectively the ability to interpret new experiments, and to apply principles to new situations. "The following year, May, 1932, students who had not elected further zoology were recalled, without specifying the purpose, and were given equivalent forms of these examinations. The same procedure was again repeated in May, 1933, and May, 1934. In this manner evidence was collected concerning the learning retained at the end of one, two, and three years after the course had been completed."

Findings.—Table LXXXXVII shows the results of the investigation.

TABLE LXXXXVII

RETENTION OF COURSE GROWTH EXPRESSED IN PERCENTAGES

Objectives	Years since completion of course		
	One	Two	Three
Informational			
Naming animal structures	23	18	10
Stating function of structures	59	47	41
Terminology	57	54	51
Other facts	70	68	49
"Intangible"			
Interpreting new experiments	111	114	119
Applying principles to new situations	127	154	158

Conclusions.—1. ". . . if the achievement of students, who later elect no further courses in zoology, was evaluated three years after a course instead of during or at the end of the course, practically all students would 'flunk' unless the passing standard was shifted radically. Whether prevailing emphasis should not be reduced on these objectives in which

learning is so temporary is a challenge which higher education cannot ignore."

2. ". . . in the non-informational objectives, such as the ability to interpret experiments new to the students and to apply principles of zoology to situations new to the student, the acquisition of learning in the course shows no loss. Some gain is actually noted in both of these objectives even for students who later elected no further courses in zoology."

STUDY NO. 232

The Measurement of Outcomes of Instruction Other than Information

By Palmer O. Johnson*

Problem.—To determine some of the merits of certain types of tests to measure outcomes from courses of science, other than the acquiring of factual information.

Method.—In a measurement program in the Junior College of the University of Minnesota under the auspices of the University Committee on Educational Research, several types of tests were devised which were aimed to measure the student's "functional knowledge," that is, his ability "to apply the knowledge he possesses to the solution of problems or new situations. This involves the ability to recall information previously acquired, to select those portions relevant to the situation, to realign ideas and synthesize them in a manner affording a basis for interpreting the situation or problem." Examples of these test forms follow:

In the diagram [showing the earth at the center of the moon's orbit, with the sun's rays coming from the right], we are looking down from the north.

1. Draw, in the diagram, the shadow of the moon as it is at annular eclipse.

* *School Science and Mathematics*, XXXIV (January, 1934), 26–33.

2. Represent in the diagram how a lunar eclipse occurs.

3. At a solar eclipse the moon must be at ( ).

If the *eccentricity* of the earth's orbit were increased, period remaining the same, our winters would be *warmer*.

If the *tilt* of the earth's axis were increased, our winters would be *warmer*.

(In this type, the student is asked to state whether a given statement is true or false and, if he considers it false, to cross out the term or terms that make the statement false and to give the correct terms. Words that are italicized are not to be changed.)

If the moon went around the earth in the opposite direction, solar eclipses would be (a) shorter, (b) longer, (c) more frequent, (d) less frequent.

Twilight is brief in the tropics because (a) the atmosphere is warm and moist (b) the ecliptic is perpendicular to the horizon, (c) the sun's diurnal path is perpendicular to the horizon, (d) of the bulge of the earth at the equator.

To test the relative validities of tests designed to measure various outcomes of instruction, a battery of six tests, four measuring the acquisition of factual information, one measuring the ability to solve problems, and one the ability to interpret new situations from the description of an experiment, was administered to two groups each of 33 students representing the upper and lower quarters of a class of 132 students in physics. The mean percentage scores of each of these groups was computed for each of the six tests.

In another experiment to determine the validity of test items designed to measure the ability to draw inferences from experimental data, the item that follows was administered to 150 students in a course in physiology, and the percentage distributions of the responses were computed for the upper quarter, middle half, and lower quarter of the students:

Directions: Select the most logical inference that can be drawn from the recorded facts.

After a frog is pithed, an injection of strychnine is made into the dorsal lymph sac. A few minutes later, the frog is touched on the leg and immediately goes into spasms, i.e., general muscular contraction. When it has

gradually relaxed, it is touched again but this time on the skin over the abdomen. The same result is noted as when it was touched on the leg.

a. The higher centers are destroyed, therefore the frog has no control over its movements.

b. Strychnine acts like curare, poisoning the motor end plate.

c. Strychnine stimulates the muscles causing them to contract and remain contracted.

d. Strychnine causes the resistance of the synapse to be increased making it more difficult for the impulse to spread.

e. Strychnine causes a more general dissemination of the initial impulses.

f. The frog goes into spasms and contractions to protect itself.

g. Strychnine poisons the blood stream.

h. Strychnine stimulates the nerves and makes them capable of transmitting impulses better.

Findings.—1. In these experiments, greater differences between the mean percentage scores of the superior and inferior groups of students were found in the ability to solve problems and to interpret new situations than in the ability to recall factual information. The former items were therefore of greater validity than the latter.

2. Not all test situations of these new types are necessarily valid, since in some cases they may fail to reveal a higher average score for the superior than for the inferior students.

STUDY NO. 233

Specific Values of Educational Films Used as Supplementary Aids

By Helen Caldwell Davis*

Problem.—"To determine the specific *kind* or kinds of information rather than the *amount* gained by the children when the film is used as a supplementary aid."

* Unpublished dissertation for the degree of Doctor of Philosophy, University of Chicago, 1932. This digest includes only the portions of this study which deal with the teaching of science.

Method.—This study consists of an analysis of the results secured with two of the 10 units of general science included in an earlier study by Wood and Freeman.[1] The materials analyzed were the responses to nine questions on the unit on atmospheric pressure appearing in the test papers of 285 pupils of the experimental (X-) group and of 302 pupils of the control (C-) group; and to 10 questions on the unit on limestone and marble appearing in the papers of 167 pupils of the X-group and of 171 pupils of the C-group. The pupils included in the X- and C-groups for this investigation were carefully paired on the basis of I.Q. and were selected so as to represent as many different schools as possible.

"*Amount* can be determined by learning the *number* of facts or statements given, without regard to whether they are like or different. In this study for *kinds* it was necessary to discover the specific and detailed items of information which could be given in answering a question correctly, to analyze each child's answer to determine which items he had given, and to discover the extent of similarity or dissimilarity between the items."

"The first step was to prepare a list of the items or facts which would give a complete answer to the question. In preparing these lists and in the final analysis of the answers, the writer studied each question independently of the others but prepared all lists for a unit before beginning the analysis of the answers to any questions in that unit. Reference material was studied to secure all the information possible on each question. This material included the children's study guide, the teacher's guide, the films, the references listed in the guides, school texts which the children would be likely to use, and any other available source giving information about doubtful points. The information thus secured was compiled in the form of a list of single and specific items. When the question required that the information be given in a

[1] *Investigations in the Teaching of Science*, Vol. II, pp. 114–119.

particular sequence, these lists of items recognized this sequence. The papers from the X- and C-groups furnished examples of the children's way of expressing specific thought units." These examples became the definition for each item. The lists formed in this way are designated as the "item-check-lists."

As a means of learning "whether the analysis of the answers through the use of such a list would yield reliable results," "the answers of a limited number of papers of the X- and C-groups in different cities were analyzed and the items found were checked on the item-check-list. A day later the analysis and checking of the answers were repeated. If the results of the two days' work were not the same, the lists were revised. The analysis and checking were made with the revised form and repeated after a day to learn whether there was a significant difference between the first and second uses of the revised form."

A study was also made of the number of children who made irrelevant or wrong statements, omitted answers, or gave items in the wrong sequence. The item-check-lists provided a means of recording these three types of data.

"No attempt was made to evaluate the items and give more credit to some than to others. Each item found in the answer was checked once on the item-check-list form, even though a child in answering a question might have mentioned that item twice."

"The test papers for a given unit were separated by cities into the X- and the C-groups. The mental ability rating of each child was recorded on his paper. The papers of the X- and C-groups of each city were arranged in rank order according to the mental scores, and numbered, beginning with the paper having the lowest score. Those of each city were then divided into three sections, each representing a different mental level. Since the cities did not all use the same intelligence test for determining mental ability, it was not possible to

use the same score for all cities as the division point between given mental levels. Therefore the division made was such that approximately the first 25 per cent of the papers formed the 'Low' section, the middle 50 per cent the 'Middle' section, and the last 25 per cent, the 'High' section." The papers for the relatively few pupils for whom no mental ability scores were available were designated as the "No-score" group.

Comparisons of the percentages of frequency of correct answers made by the pupils of the X- and C-groups in the pretest were made by computing the coefficients of correlation by the Pearson Product-moment Method and by computing the significance of the differences by the ratios of the differences of the two percentages of frequency to the P.E. of this difference.[1]

The significances of the difference in the final scores of the two groups were likewise determined by the ratio of the differences to its P.E.

Conclusions.—1. "The film was distinctly more effective than other forms of instruction in presenting items of the type dealing with action or activity; other forms of instruction were more effective than the film for items of the type dealing with objects."

2. "The clearness with which the specific items were presented in the film conditioned the effectiveness of this mode of instruction."

3. "The film was not more valuable for the children of one than for another of the three mental levels." ". . . the film will not enable the child of a high mental level to be more superior to the child of average ability than he would be without this aid."

4. "The film was more effective than other methods of instruction in some units of subject matter and for certain types of questions in reducing the percentage of children

[1] K. J. Holzinger, *Statistical Methods for Students in Education* (Bostor: Ginn and Company, 1928), 243–244.

giving irrelevant and wrong statements, and less effective in other units and types of questions."

STUDY NO. 234

A Study of Three Methods of Teaching Science with Classroom Films

By W. J. Hall*

Problem.—To determine the relative values of three methods of teaching classroom films, in effecting retention of scientific knowledge.

Method.—The following methods were used in this investigation: With Method A, the pupils were informed at the beginning of the class period that a film supplementing the classwork was to be given, and that a test would follow the film. They were asked to be on the alert for important information shown in the film, especially for such subject matter as had previously been discussed in class. The pupils were "urged to ask questions or to request the re-showing of parts not clear during the showing of the film." They were free to take down notes if they wished. The film was then projected and at the discretion of the instructor comment was made, still pictures[1] (especially of animated diagrams) were shown, and the machine was stopped, speeded over unessential material or slowed down for important detail. Blackboard diagrams to supplement the film were sometimes used. A class discussion guided by the instructor so as to emphasize important principles, followed the showing of each film. A completion test on a prepared slide,[2]

* *School Science and Mathematics*, XXXVI (December, 1936), 968–972.

[1] See study of the use of strip film by Brown, *Investigations in the Teaching of Science*, Vol. II, p. 119 (Footnote).

[2] Frank† arrived at the following "tentative conclusions" as a result of analyzing the critical reactions of about forty pupils to various uses of

† J. O. Frank, "An Experiment in Visual Education," *Journal of Chemical Education*, X (February, 1933), 90–91.

was then projected on the screen. The pupils wrote their answers, exchanged and marked the papers. While marking papers they were given opportunity to question any answer. This activity often started worthwhile discussion between pupils holding conflicting viewpoints.

With Method B, the same procedure was followed as for Method A with the exception that no test was given.

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slides in teaching chemistry:

1. "Students greatly prefer to see a set of slides and to hear a complete lecture at the beginning of a unit rather than later."

2. "A whole set of slides covering a given unit [is not only to be preferred by the teacher, but] is better received and given more attention by students than a few slides shown at intervals or covering only a few items."

3. Slides used in teaching chemistry vary enormously in their teaching values. Many slides in standard sets, and even entire sets, are wholly worthless as teaching aids and sometimes present materials "which have been obsolete for years."

4. "One of the greatest values resulting from the use of slides [even some which seem to possess little teaching value] lies in the interest they induce."

5. "When either charts or tables can be used to teach a given item, the students prefer the charts. When diagrams or tables can be used, they prefer the diagrams. Yet when the essential figures in a table can be made conspicuous in some way or other, the students claim that they do learn easily from the tables. Students prefer historical data presented in tabular form by means of a slide rather than in story form on the printed page."

6. "Students believe they learn more from slides carrying printed captions and printed notations labeling the various important features of the apparatus, device, or process shown by means of slides. Lettered parts are difficult to read and understand unless much time is given."

7. In descending order of legibility as legends or labels on slides are boldface type, typewritten type, hand-lettering, and script.

8. "One great value of slides lies in the fact that time enough can be given an item so that its details can be mastered."

9. "It is evident that slides are not equal to charts for showing apparatus of intricate design, or other material which has to remain in view for a considerable time."

With Method C, "the same procedure was followed as for Method A with the exception that the test questions were projected on the screen at the beginning of the class period for a pre-reading and remained on the screen below the projected film throughout the showing of the film. Students were requested to write the answers as soon as they knew them. Care was taken in preparing questions to see that they had the same sequence as the film, and all thought questions were placed at the end of the list."

Six films were selected on the basis both of their relation to the geological topics which were then being studied, and of their special construction for classroom use.

The three methods were used in rotation with each of three second-semester, first-year classes which were studying general science in the North Division High School of Milwaukee, Wisconsin. Each class saw each film once; two films were used with each method.

"A pre-test was given two days previous to the showing of each film. The same test was used in Methods A and C, as testing was a part of the method." Two weeks after the showing of the first three films and four weeks after the showing of the last three, the test was administered again in all classes to measure retention. "The difference between the pre-test mark and the final retention-test mark was taken as the change produced by each of the three methods." To eliminate any possible disadvantage with Method B, which might result from the fact that this method provided no "use of the test questions between the pre-test and the final retention test," a test was also given with the last three films "on the day following projection in each of the three methods."

Means, S.D.'s, and P.E.'s of means were computed and the significance of differences was determined by comparing the difference between each pair of means with four times the P.E. of this difference.

Findings.—In every case there was found to be a significant difference in favor of Methods A and C as compared with Method B. In each case, moreover, a positive difference was found in favor of Method C as compared with Method A, but none of these differences was statistically significant.

STUDY NO. 235

The Learning Value of Some Motion Pictures in High-school Physics and General Science as an Illustration of a Simplified Technique in Educational Experimentation

By Ralph K. Watkins*

Problem.—To determine "whether or not boys and girls in a high-school class could learn facts of physics (or of general science) as a result of viewing available films of supposed educational value" in these fields.

Method.—This investigation was carried on in 1929–30 with a class of 16 pupils in physics, in the University of Missouri High School, and in 1930–31, with two classes of respectively 25 and 35 pupils in general science, in the Kansas City Junior High School of Kansas City, Kansas. Identical techniques but different materials were used with the class in physics and the classes in general science. For the former group six films dealing respectively with "Temperature Control," "Magnetism," "How We See," "The Magic of Communication," "Wizardry of Wireless," and "Revelations of the *X*-ray" were selected to supplement the regular class work. For the latter groups, four films, presenting respectively "Butterflies and Moths," "Life," "Air," and "Volcanoes," constituted the supplementary materials.

* *The Educational Screen*, X (May, 1931), 135–137, 156–157.

In a preliminary showing, the investigator "ran each film slowly and listed items of sufficient importance to the . . . class to justify their inclusion in a test upon the film." A "home-made objective" test, consisting of true-false and of multiple-response items of two, three, and four choices, was constructed to measure knowledge of the "facts and ideas" contained in each of the selected films. In each test only those items were retained, concerning the scoring of which there was no question.

A class "was moved to the projection room" and the test on the films was given. The film was then shown "without further introduction than an announcement of the general nature of the content. No lecture, explanation, or discussion other than the subtitle in the film itself accompanied the showing. After the showing a few minutes were allowed for pupils to ask questions about the film. The teacher attempted to answer these. No other lecture or explanation was given. The teacher did not quiz the class." The same test that had been given before the film was shown was immediately readministered. The mean gains and the mean percentage gains with each film were computed.

Findings.—1. The mean gains of the class in physics with the six films ranged from 28 per cent to 106 per cent.

2. The mean gains of the pupils in general science with the four films ranged from 33 per cent to 146 per cent.

Conclusion.—"Undoubtedly these pupils learned something from watching films on science topics. It seems probable that other pupils would learn from watching well selected films on science topics."

STUDY NO. 236

Sound Motion Pictures as an Aid in Classroom Science: A Comparative Study of Their Effectiveness at the Junior-college Level of Instruction

By C. C Clark*

Problem.—To determine the relative values of educational sound motion pictures and silent motion pictures, and of educational sound motion pictures and lecture demonstrations as means of conveying concrete scientific knowledge or information to students of junior-college level, and of stimulating and maintaining the interests of such students.

Method.—This experiment was carried out with two "highly homogeneous" groups, each composed of approximately three hundred Freshmen enrolled in a survey course in science offered in the School of Commerce, Accounts, and Finance of New York University. "The groups were selected on the basis of of the students' scores on the Army Alpha Examination and the O'Connor Vocabulary Test, Work Sample No. 95, Form AA, in order to make them as nearly equal as possible in mental capacity."

"The experiment consisted of two parts corresponding to two semesters of the school year." "During the last part of the experiment the students were rotated between the two groups."

* Dissertation for the degree of Doctor of Philosophy, New York University. This digest is prepared from three published reports of this study: "Sound Motion Pictures as an Aid in Classroom Teaching," *The School Review*, XL (November, 1932), 669–681; "Sound Motion Pictures as an Aid in Teaching Science," *Science Education*, XVII (February, 1933), 17–23; and "The Talking Movie and Student's Interests," *Science Education*, XVII (December, 1933), 312–320. A report of this study appears also under the title, "The Effectiveness of Sound Films as Aids in Classroom Teaching," in *Education*, LIII (February, 1933), 337–342.

In the entire investigation eight sound films and eight silent films were used.

Three types of comparisons were made: (1) in one, educational sound films were used with the experimental (X-) group and identical silent films with the control (C-) group; (2) in a second, sound films were used with all the students to illustrate certain divisions of the subject matter, and silent films were used with all the students to illustrate certain other closely related division of the subject matter; and (3) in a third, sound motion pictures were used with the X-group and identical lecture demonstrations with the C-group.

The first two of these comparisons were made "with the films relating to the biological sciences where identical sound and silent motion pictures and closely related sound and silent films are available." The sound films used were of the lecture type in which the sound consisted only of a spoken explanation and discussion of the items in the film by a speaker who was not seen in the picture.

The third comparison was made with films relating to the physical sciences. In these "the sound was a vital and integral part of the scenes in the picture. When an explanation was made, the speaker was shown in the picture and was working with the object talked about. All sounds which were natural to the objects in the picture were reproduced by the films. The sound in this case has the effect of being a part of the activities of the picture, rather than about these activities." "It was impossible to compare these sound films with silent films directly, as no silent films identical with these sound films are available."

"In order to get a secondary cross comparison of sound and silent films relating to the physical sciences, certain silent films on additional divisions of the subject matter of the course were shown to the X-groups, and lecture demonstrations [including the same materials shown] in the silent pictures were given to the C-groups."

The results of the experiment were evaluated by means of a battery of written tests constructed by the investigator and "relating to the factual content of the films." Test I, consisting of 60 items of the recall type, was based on the biological films. This test was divided in three parts, the first of these covered the films of which the sound editions were used with the X-group, and silent editions of identical content with the C-group (First Comparison). The second part covered the two sound films shown to both X- and C-groups (Second Comparison). The third was based on the two similar silent films shown to both groups (Third Comparison). This test was given once only, after the films had been used.

Test II consisted of 38 items of the multiple-response type, based on the films presenting phases of the physical sciences. Because of the conditions of the experiment, this test was administered in six parts.

"The reliability of the different parts of the comprehensive examination was determined by calculating the half-test coefficients of correlation. From these coefficients the reliability coefficients were determined by using the Spearman-Brown Formula." These reliability coefficients ranged from .85 to .90.

Test II was administered both before and after the films had been shown. The significance of the results was determined from computations of the experimental constant (difference in mean scores of the X- and C-groups divided by the P.E.s of the difference of these mean scores) for the three parts of Test I and the six of Test II.

Two methods were used in measuring interests. One method was to use an interest test, based upon the activities period, and requiring the student to "record in a variety of ways the basis of best interest." Such a test was administered at the beginning of the study and again five months later, after the students had had the advantages of the films and demonstrations. The changes of choices were taken as a meas-

ure of the effectiveness of these types of visual aids in stimulating new interests; the consistency of choices was considered as indicating the effectiveness of the visual aids in maintaining and heightening an interest.

"The second method used in measuring interest was based upon the consideration that the extent of the sustained attention of the student is indicative of the immediate interest which he had in the topic being presented. The method employed a distracting stimulus and the photographic technique to measure the extent of this sustained attention. That the degree of attention manifested is indicated by attentive behaviour which can be measured objectively by measuring motor responses is the thesis involved in this measurement of sustained attention of the students as stimulated by sound films, silent films, and lecture demonstrations."

"The distracting stimulus was provided by a ringing bell or a flashing light at a point in the room different from the point on which the students' attention was being focused by the motion picture or lecture demonstration. The number of students who were distracted was determined by photographing the class after a sufficient reaction time following the stimulus. The photographic apparatus was mounted in the front of the classroom. The entire apparatus was electrically operated so that the instructor could produce the distracting stimulus and photograph the class at any instant by pushing a single control button. The number of students who were distracted was determined by counting, in the photograph, the students who had looked away from the center of attraction."

Findings.—1. The students having the silent films made higher scores than did the students having the sound films of the lecture type, "in which the sound consisted only of a speaking voice accompanying the scenes of the pictures . . ." The differences found were statistically significant "and indicate clearly the superiority of the printed caption over the lecture type of sound film."

2. Sound films "of the type in which the sound is a vital and realistic part of the pictures" were found to be more effective than silent films in comparison with lecture demonstrations.

3. The results of the experiments in which three silent films were compared with identical lecture demonstrations showed results which "seem to indicate an advantage in favor of the demonstration used over the silent films used."

4. The sound films "in which the sound is a vital and realistic part of the pictures" were found to be equally as effective as the lecturer performing and explaining the actual demonstrations.

5. Results of the interest tests revealed differences "believed large enough to be significant" in favor of sound films over demonstrations with respect to both maintaining initial interests and in stimulating new ones. "Similar comparisons of silent films and lecture demonstrations . . . fail to show an advantage of either the films or demonstrations in maintaining previous interest or stimulating new ones."

6. With the second type of interest measurement, "the difference between the effectiveness of the sound films and the silent films is inconsequential. As measured in this manner, however, both the sound films and silent films are significantly more effective than the classroom demonstrations in stimulating students' interests."

Conclusions.—1. "The use of a spoken lecture, . . . in place of the printed captions, in an educational moving picture is most likely to detract from its value in conveying specific information."

2. "When a sound film is so produced that the sound is a vital part of the picture and adds to the reality of the scenes presented, such a film is as effective as actual classroom demonstrations and more effective than a silent film for conveying exact information."

3. "Educational films can be used effectively as a means of arousing and increasing students' interests in the topic studied.

In this respect sound films are apparently more valuable than silent films."

STUDY NO. 237

Measuring the Effectiveness of Sound Pictures as Teaching Aids

By Varney C. Arnspiger*

UNIT I

Problem.—To determine by experimentation the "relative effectiveness (a) of teaching with the aid of certain educational talking pictures in the field of natural science in Grade V; and (b) of the usual methods of classroom instruction."

Method.—This experiment was conducted with 950 fifth-grade pupils in 16 pairs of matched classes in five cities: New York and Schenectady, New York; Camden and Elizabeth, New Jersey; and Baltimore, Maryland. The classes were matched on the bases of scores on the Pintner Rapid Survey Intelligence Test, Form B, and of social background as determined by the environments represented by the residential districts in which the pupils composing the classes lived. The two teachers of each pair of classes were likewise paired on the basis of ability as judged by local school authorities and in four of the five cities, also, on the average of their ratings by the local school authorities and of their scores on the Jacobs Teacher Efficiency Rating Scale. For the five cities combined "there was a slight [though not statistically significant] difference in the mean intelligence quotients favoring the

* Dissertation for the degree of Doctor of Philosophy, Contributions to Education, No. 565. New York: Teachers College, Columbia University, 1933. Only the parts of this dissertation which deal with the teaching of science are here included. A summary of this study, by the investigator, appears in *The Educational Talking Picture* (Frederick L. Devereux and Others) (Chicago: The University of Chicago Press, 1933), 76–93.

experimental [X-] group" and a "composite average . . . slightly in favor of the control [C-] teachers."

Four instructional units were prepared on *Butterflies*, *Beetles*, *Amphibians*, and *Growth of Plants*. Preliminary tests, consisting of approximately one hundred fifty items of six types: true-false, two-choice, multiple-response, one-word completion, essay completion, and graphic representation were constructed for each unit. These types of test items were assigned weightings on a statistical basis. The tests were administered to more than three hundred fifty children who were in the second half of the fifth grade in schools of six cities of New York State. After the tests had been scored, the items were arranged in order of difficulty. Those which were ambiguous and those which were found to be either too simple or too complex were deleted. "Each of the resultant initial tests contained approximately fifty items."

These tests of the childrens' initial information concerning the four units were administered to both the X- and the C- groups. On every test, except that on *Beetles*, the average score made by the C- group was higher than that made by the X- group, and on one test (*Growth of Plants*) significantly higher (statistically).

"The class teaching of the four units of instruction began two weeks after the administration of the intelligence and initial tests." Each unit was taught during a two-weeks' period. It received 150 minutes of instruction divided into five 30-minute periods. All teachers were furnished with identical instructional guides prepared in advance for all the units. "The materials for the films were selected from these instructional guides and were developed into suitable continuities which served as the basis for the final production of the talking-picture subjects."

The participating teachers of both groups followed uniform procedures. The teachers of the X-groups agreed to meet at least one week before beginning their instruction on the subject

of each picture, and to view and make notes on the picture. The pictures were shown to the X-groups in 10-minute periods at the first, third, and fifth periods of each unit. Thus the showings of the talking pictures occupied one-fifth of the class time for the X-groups. "The showings were preceded or followed by discussion of the picture aims and content."

"The teachers of the C-groups were allowed to use any teaching device, except motion pictures . . ."

No teacher was permitted to see any of the tests, and no teachers of C-classes were allowed to see any of the talking pictures during the experimental period.

"At the end of each unit of instruction a comprehensive final test was administered." Four weeks after the completion of the fourth unit of instruction, and 14 weeks after the administration of the initial tests, these initial tests were repeated as recall tests. Coefficients of reliability were computed for initial, final, and recall tests and were found with few exceptions to be high.

In order to determine the significance of the test results the "critical ratio of the difference between the means of the X- and C-groups was computed (the difference between the means divided by the standard deviation of the difference between the means)."

Findings.—1. "The differences in gains for the combined cities were greater for the X- than for the C-groups in the case of every individual unit studied. The critical ratios indicate that differences favoring the X-groups were statistically significant in every unit . . ."

2. "In the results of those test items the answers to which were presented both by the talking pictures and by the units of instruction . . . the per cents of superiority of the X-groups over the C-groups for all cities combined ranged from 20 to 60 per cent."

3. ". . . the X-groups achieved practically as much as the C-groups in the subject matter which was presented in the units

of instruction and not in the films." "It would seem then, that the gains of the X- over the C-groups throughout the experiment were made without sacrificing the learning of subject matter not presented specifically by the films."

4. ". . . there was a statistically significant difference in mean gains favoring the X-classes of both the low and the high intelligence levels."

5. From the results of the recall tests "it appears that the talking pictures used in this experiment made a lasting contribution to learning in . . . natural science . . ."

UNIT II

Problem.—"To make an analysis of the composition elements of certain scenes of the talking pictures used in the experiment, this analysis being treated in such a manner as to serve as an introduction to the study of the relative effectiveness of these elements of composition."

Method.—"An analysis was made of those individual items occurring in both the initial and final tests, the answers to which were furnished either directly or indirectly by the films as well as by the units of instruction. These items, numbering 186, were ranked according to the superiority of X-pupils over C-pupils in the number responding correctly to the test items."

"Those items occurring in the highest and lowest quarters of the distribution were analyzed in terms of the picture-composition elements utilized in the presentation of concepts which they measured. This analysis involved a consideration of the following elements: (1) type of photograph (whether natural, slow motion, animation, superimposed, composite, or microscopic); (2) focal length (whether close-up, medium, or long shot); (3) scene length (time of scene in seconds); (4) quality of scene lighting (specific scenes rated on the basis of a five-point scale as follows: "Excellent," "Very Good," "Good," "Fair," and "Poor"); (5) sound, speech, and picture sound; (6) time section of film in which scene occurred (during the minute

of the film from the first to the tenth); (7) repetition (including cutback of scenes and repetition of the same ideas with varied scene and speech treatment in one or more instances); and (8) integration of audio-visual elements."

Conclusions.—1. "Much has been said about the superiority of the film in which sound other than speech is presented, but from this study there seems to be no direct evidence to prove that such sound is necessary to clarify concepts, unless it is used to present concepts directly involving such sound."

2. "The most important elements of composition involved in producing an effective educational sound film seem to be . . . the proper integration of audio-visual elements, a generous use of the 'close-up' focal length, excellent lighting of scenes, and a judicious use of repetition."

STUDY NO. 238

The Sound Motion Picture in Science Teaching

By Phillip Justin Rulon*

Problem.—To determine the extent to which the learning of general science is affected by the employment of sound films as supplementary aids to teaching materials during the regular class period.

Method.—Three groups of pupils, an experimental (X-) group of about four hundred fifty pupils in 16 classes, a control (C-) group of about twelve hundred pupils in 55 classes, and a zero (Z-) group of nearly three hundred pupils in 20 classes, who were studying general science in three suburbs of Boston of respectively 102,000, 36,000, and 72,000 population, "were exactly matched with reference to chronological age, mental

* Cambridge, Massachusetts: Harvard University Press, 1933. This digest is prepared chiefly from a report of this study under the title, "Sound Films *versus* Traditional Methods in Science Teaching," in *The Nation's Schools*, XII (November, 1933), 31–34.

test score, and science information score at the beginning of the experiment. With respect to the excellence of their teachers, the three groups were as nearly balanced as possible with the use of ratings of excellence. The teachers of one group carried approximately the same teaching load as did the teachers of any other group. The pupils of all three groups studied in classes of approximately the same size, for the same number of minutes a day, the same number of days a week, and at the same time of day. The amount of assigned homework was the same for the two instructed groups (the X- and C-groups). The proportion of boys to girls was similar in all three groups."

The X- and C-groups were further "balanced with respect to all factors commonly considered responsible for children's achievement. These factors included socio-economic status of community of residence as measured by occupational level of the adult males in the community. Both groups studied in school systems organized on the junior-high-school basis and both groups were composed of children who were taking general science as a required part of their course of study. In all the co-operating schools general science was taught only in the ninth grade and was offered five days a week, one period a day. All of these schools had used the same basic textbook in science and approximately the same collateral reading texts were available for the children."

A special text of eight chapters, patterned after materials in representative general-science textbooks, "was prepared to supply instructional material in physiography and biology for a six-week period." A reel of sound motion pictures was selected to supplement each chapter of this textbook. ". . . the text was entirely self-contained and self-sufficient and made no reference to the films, nor did the films make any reference to the text. The films in no way replaced the usual methods of classroom instruction. Teacher and pupil discussion, projects, collateral reading, supervised study, and other modern teach-

ing methods were employed" with both X- and C-groups. The C-group studied the textbook in the usual manner; the X-group "studied from the textbook but in addition they were shown in connection with each chapter (and during part of the regular class period) the reel of film which supplemented it." The Z-group "did not study the general-science material used in the experiment but instead continued in their accustomed way to study other general-science topics chosen so as not to overlap the experimental instructional material. This group was called the Z-group since its test score at the end of the experiment represented the result of zero instruction."

Objective tests were constructed to measure both factual information and reasoning from factual information. Examples of the types of items follow:

Fact: The number of planets in the solar system is (a) 9; (b) 3; (c) 2,000.

Causal relationship: The dust blown by winds usually comes to rest (a) at the same altitude as that from which it was blown; (b) at a higher altitude; (c) at a lower altitude.

Deduction item: When the earth movements cause the sea-bottom to rise above the surface of the water, the resulting shore line is (a) smooth and regular; (b) cut-up and irregular; (c) smooth, but with a few large bays.

Of the total of 660 items, all of which were based on the textbook used by both the X- and C-groups, 530 were three-choice multiple-response items like those just cited, and 130 were two-choice items based on pictures, like the following:

More waterfalls are found in places like A B.

With this type the pupil studied two pictures labeled "Picture A" and "Picture B," which accompanied the test, and having decided which one fulfilled the conditions imposed by the item, drew a circle around A or B to designate that picture.

". . . since the experiment aimed at measuring instructional effect, the test items employed were tried on uninstructed children before being used in this experiment and all items

that many children answered correctly without having had instruction in general science were deleted from the tests."

These tests in their final form were administered for immediate recall at the end of the six-weeks' instruction period and again for retention more than three months later. "During this interval the experimental material did not again appear in the study program." "To measure the amount of learning accomplished by the C-group . . . the mean test score of the Z-group was subtracted from that of the C-group, and the difference, ascribable to the instructional effectiveness of the control teaching procedure, was called the control gain. Similarly, subtracting the mean score of the Z-group from that of the X-group gave the film gain." The significance of each difference in mean gains was obtained by dividing the difference in mean gain by the S.E.[1] of this mean gain. The significance of each "percentage of superiority" was obtained by dividing the percentage of superiority by the S.E. of this percentage of superiority.[2]

Findings.—1. The mean gain of the X-group exceeded that of the C-group immediately at the end of the period of instruction by 20.5 per cent with a P.E. of 2.6 per cent. These results are "sufficiently conclusive to satisfy the most rigorous criteria of a statistical significance." Immediately following the period of instruction, however, the X-group made lower scores on those test items which were based on the text materials only. "It was a vastly superior performance on the text-and-film-both items that enabled this group to excel the C-group in immediate learning."

2. The mean gain of the X-group exceeded that of the C-group by 38.5 per cent with a P.E. of 4.4 per cent, when the tests were re-administered three months after the experiment had been completed. ". . . this large superiority in the

[1] $\sigma_{M1-M2} = \sqrt{\sigma_{M1}^2 + \sigma_{M2}^2 - 2rM_1M_2\sigma_{M1}\sigma_{M2}}$.

[2] $\sigma_{\frac{a}{b}} = \frac{1}{b}\sqrt{\sigma_a^2 + 2\frac{a}{b}r_{ab}\sigma_a\sigma_b + \frac{a^2}{b^2}\sigma_b^2}$.

film group's retained gain may be even less reasonably ascribed to chance than could its superiority in the earlier testing." In the retention tests the X-group scored as well as the C-group on the items based only on the text materials, and therefore "no sacrifice in the learning of any one part of the subject matter was made in accomplishing the film-caused increase in another part."

3. "When the tests were scored separately for achievement on 'rote memory' items and 'thought' items, the film-taught children exhibited themselves superior on 'thought' items and to an even greater extent than on the 'rote memory' items."

Conclusions.—1. "With reference to teaching effectiveness, . . . we are able to conclude that in terms of retained achievement the film-supplemented procedure was 35 per cent more efficient than the unsupplemented method."

2. "When good and generally supplementary sound motion pictures are introduced in connection with modern teaching methods in general-science instruction, we may expect the resulting increase in pupil learning to be an amount in excess of 20 per cent when measured in terms of permanent acquisitions."

STUDY NO. 239

Comparison of Verbal Accompaniments to Films

By William Francis Einbecker*

Problem.—To determine the relative values of talking pictures and silent pictures.

Method.—This experiment was conducted during the spring of 1932 in the Deerfield Township High School, Highland Park, Illinois, with two equivalent ninth-grade classes in general science and two equivalent eleventh- and twelfth-grade classes in physics. The two classes in general science consisting each of 48 pupils, were equivalent with respect to I.Q.'s

* *The School Review*, XLI (March, 1933), 185–192.

determined from the pupils' scores on the Terman Group Test of Mental Ability; their median I.Q.'s were respectively 102.5 and 100.5 and their ranges of I.Q. respectively 73–137 and 75–139. The two classes of physics, numbering 22 pupils each, were similarly equivalent with respect to I.Q.'s each having a median I.Q. of 113.5 and having ranges of I.Q. respectively 91–136 and 94–134. Also these two classes in physics were made up of pairs matched on the basis of sex, I.Q., and scores on the Sangren-Marburger Initial Test in Physics.

The rotation method was used in determining the relative values of the following methods of presentation:

1. Presentation of a silent film without captions or oral comments of any kind "other than a statement of the purpose of this unusual procedure and a plea for co-operation"
2. Presentation of a silent film without captions but with oral comments by the teacher
3. Presentation of a silent film with captions
4. Presentations of a silent film with captions and with oral comments by the teacher
5. Presentation of a talking picture

Method I was used only with a fifth group of 23 pupils in general science. After both reels of the picture had been shown to this group a test was given. The resulting scores were compared with the scores on the same test of all four of the equivalent groups when they viewed one or the other of these same reels in accordance with both Methods II and V. Comparisons were made also of the scores made by the two classes of physics in viewing two other films by Methods III and IV, and a fourth film by Methods II and V.

All conditions concerned with the presentation of the four films by the various methods were carefully controlled. The teacher's comments in Methods II and IV "were directed toward explaining technical points, elaborating on the major ideas of the picture, or directing attention to certain features of the picture which were thought to be especially significant.

The teacher lectured from notes made during a preliminary showing of the picture and from the continuity. While the lecturer avoided duplicating the regular sound accompaniment, there was no attempt to avoid discussing the subjects covered in the talking part of the picture. The principal difference between the sound [Method V] and the teacher accompaniments was that the teacher avoided making comments which were not illustrated in the film and tried to explain details found in the picture more fully than was done on the screen."

The tests prepared for measuring the results with all four films were of the diagram and completion types, with an additional diagram test of 25 items constructed for one of the films. The reliabilities of these tests "determined by applying the Spearman-Brown Formula for predicting the reliability of a lengthened test to the correlation coefficient for the odd-numbered and the even-numbered questions," ranged between .71 ± .01, and .93 ± .01.

Conclusions were based upon a consideration of median test scores made by the various groups with the five methods.

Conclusions.[1]—1. "Verbal accompaniments increase the comprehension over that secured from the film without caption or comment, but it is immaterial whether it is the teacher or the speaker in the talking picture who comments."

2. "Both carefully-planned comments of a descriptive character and directions calling attention to particular terms or features increase the pupils' *immediate* understanding and memory of a picture."

3. "If the added comments of a teacher produce any *permanent* effect of the pupils' comprehension of a silent picture with captions, completion tests are measures too coarse to show this effect. Probably the effects of such comments are largely temporary increases in comprehension aiding memory of the

[1] ". . . the conclusions of this study are based on comparisons of pictures of the expository type. The conclusions should not be applied to pictures involving dialogue or dramatic action."

picture itself rather than increases in the comprehension of the topic illustrated by the picture."

4. "Silent motion pictures accompanied by the teacher's comments are superior to both talking pictures and silent pictures with respect to the learning of new technical words or unfamiliar names."

5. "The results of this study indicate that, so far as instructional values in science are involved, the printed caption accompanied by the oral comments of the teacher forms visual images and oral stimuli which are at least as effective as the impressions formed by the talking picture."

STUDY NO. 240

The Length of the Period and Pupil Achievement in High School

By George E. Denman* and Thomas J. Kirby

Problem.—To determine the relative efficiency of long periods (from 55 to 65 minutes in length) and short periods (from 40 to 45 minutes in length) as indicated by pupils' scores on objective tests in general science and physics.

Method.—The scores made on the Iowa Academic Meet Tests in physics by the 599 pupils in 16 Iowa high schools of the North Central Association, in which long periods were used, were compared with the corresponding scores made by 600 pupils in 16 other North Central high schools of Iowa in which short periods were used. Each school in one group was paired with one of the other group "having approximately the same enrolment, the same number of teachers, and the same general educational conditions."

* *The School Review*, XLI (April, 1933), 284–289. Only the portions of this extensive study which deal with the teaching of science are here presented.

A similar comparison was made of the scores of respectively 512 and 550 pupils who were studying general science in two groups of 10 high schools each, selected and paired on the same bases as the 16 pairs of schools used in the study of physics. The significance of the differences in these achievement scores was determined by computing the critical ratio, that is, the difference in average scores divided by the standard error of these differences.

Findings.—The critical ratios for the groups in physics and general science were respectively 0.5 and 0.8 in favor of the long period. "In the case of the physics the total recitation time for the long-recitation group was not much greater than the total time for the short-recitation group because some schools using long periods gave only five periods a week to physics, while schools having shorter periods gave the customary seven periods to provide for laboratory work."

STUDY NO. 241

The Effect of a Shortened Class Period upon Achievement in High-school Physics

By Henry Ward Duel*

Problem.—To determine the effect of shortening the class-period, upon the subject-matter achievement of students in high-school physics.

Method.—This investigation was made in West High School, Minneapolis, with pupils enrolled in four classes of physics under each of two teachers. Eighteen pupils of one of Teacher A's classes were paired with 18 pupils in Teacher A's other three classes on the bases of I.Q.'s and scores on an initial objective test of 75 items scaled according to McCall's T-Score technique.[1] Similarly, 30 pupils from one of Teacher B's

* *Science Education*, XX (October, 1936), 157–159.

[1] W. A. McCall, *How to Measure in Education* (New York: The Macmillan Company, 1922), 272–291.

classes were paired with 30 pupils in Teacher B's other three classes. The unpaired pupils in the eight classes were disregarded in so far as the experiment was concerned. "Statistical treatment of the data shows no significant differences in means or variabilities between the two groups . . ." The experimental (X-) group of each teacher had 24-minute periods; the control (C-) group of each teacher had respectively a 54-minute and a 56-minute period.

The period occupied by the experiment extended from March 11 to April 10, 1935. "The subject matter covered consisted of 'the mechanics of liquids,' 'the mechanics of gases,' and 'molecular physics.'" "The lecture-demonstration was used for the laboratory work. Teacher A performed all the laboratory exercises for both his classes and Teacher B's classes."

"The usual school conditions prevailed during the interval of this study. There were interruptions for auditoriums and other extracurricular activities, but the number of such interruptions was neither more nor less than might ordinarily be expected during a like interval at any time during the school year." Conditions in all classes were kept as nearly constant as was feasible except the experimental factor, which was the length of the class period.

The initial test was repeated as a final test at the end of the experiment. The significance of the difference between the mean initial and final scores of the paired groups of each teacher was determined from the standard errors of the differences. Also the comparison was made of the gains made by members of the separate pairs.

Findings.—1. With Teacher A's classes, a slight, though not statistically significant, advantage in mean scores was noted for the C-group; with Teacher B's classes, this result was reversed.

2. When gains made by members of the separate pairs were considered, "in 62.5 per cent of the cases, students in classes

which met for 24 minutes per day did as well as, or better than, students in classes which met for 54 or 56 minutes per day."

Conclusions.—1. ". . . the 54-minute class period could be shortened a considerable amount without any serious loss to the students . . ."

2. ". . . the effects of an occasional shortening of the class period are negligible."

STUDY NO. 242

Comparison of the Effectiveness of the Single Laboratory Period and the Double Laboratory Period in High-school Chemistry

By L. W. Applegarth*

UNIT I

Problem.—To determine whether conventional experiments in chemistry can be performed individually by pupils in less time than is afforded by a double period.

Method.—During a period of four weeks, three classes of about thirty-four pupils each were instructed to perform individually each of eight experiments as quickly as possible without sacrifice of complete comprehension. The numbers of completed experiments were recorded at five-minute intervals.

Findings.—The times required in performing the experiments individually were as follows: 38.2 per cent were performed in 40 minutes; 14.8 per cent in 45 minutes; 19.6 per cent in 50 minutes; 7.9 per cent in 55 minutes; 10.5 in 60 minutes; 3.6 in 65 minutes; 1.8 in 70 minutes; and 3.5 in 75 minutes.

Conclusion.—"These data indicate the possibility of shortening the double laboratory period."

* *School Science and Mathematics*, XXXV (June, 1935), 627–633.

UNIT II

Problem.—To determine the relative effectiveness, as measured by retention of factual information, of the single and the double laboratory period in high-school chemistry.

Method.—The members of each of two classes of chemistry were paired individually with the members of a third class used as a control, on the bases of averages of chronological age, marks for the previous semester in chemistry, I.Q.'s, and "classification." The experimental materials consisted of two groups of 10 experiments each. The rotation method was used. Sections I and III performed the first 10 experiments in a single period while Section II performed the same experiments in a double period; Section II then performed the second 10 experiments in a single period while Sections I and III performed the same series of experiments in a double period. All factors except the experimental factor (difference in time allotment) were kept constant.

"Eight tests were given to cover [the] 20 experiments. Each test consisted of 25 blank-space items designed to measure retention of facts such as formulas, equations, names and facts stressed in the experiment, and laboratory procedure. Each test item was scaled for difficulty on the basis of the percentage of correct answers.[1] Each test was administered as a pre-test and as a final test." The results were computed in terms of the mean differences between the pre-test and the post-test scores on these tests. The pupils were asked at the time they took each test to express their preferences with respect to the two methods. For consideration of these expressions of preference, the pupils of each group were divided into three groups determined on the basis of I.Q.'s; those having I.Q.'s above 105; those having I.Q.'s between 95 and 105; and those having I.Q.'s below 95.

[1] K. J. Holzinger, *Statistical Methods for Students of Education* (Boston: Ginn and Company, 1928), 224–229.

Findings.—1. About an equal number of the test results show advantages in favor of each of the two period lengths.

2. About an equal number of these pupils expressed a preference for each of the two plans.

Conclusion.—Neither method shows an advantage over the other either for the classes as a whole or for the three intelligence-level groups within the classes.[1]

[1] An investigation of the relative values of single laboratory periods and double laboratory periods for classes in high-school chemistry is reported by Sugar.* Three classes who were beginning the study of chemistry under the investigator in Northeastern High School, Detroit, and two similar classes under another teacher were equated on three bases: I.Q.'s, ages, and initial scores on tests constructed by the investigator to measure factual knowledge resulting from the laboratory experiments performed in connection with the course. The groups were considered to be equivalent on each basis when the difference in means divided by the S.D. of the difference in means was less than 1.00. The investigator followed the conventional schedule of three regular class periods and two double laboratory periods per week with two control (C-) classes, and a schedule of three regular class periods and two single laboratory periods with a third experimental (X-) class. The second teacher conducted one class by each of these two plans. In the classes of the investigator, 34 pupils in the two C-classes were paired with 21 pupils in the X-class; in the classes of the second teacher 14 pupils in the C-group were compared with 11 in the X-group. All factors were kept identical in the C- and X-groups except that the X-groups were allowed only half as much time in which to perform the laboratory exercises as were the C-groups. The investigation continued for an entire semester during which both the X- and the C-groups performed all the laboratory exercises regularly performed as part of the first semester's work in chemistry. The initial test was again administered at the end of the semester as a final test to all groups, and comparisons were made between the mean gains of the paired groups, by dividing the difference in mean gains by the S.D. of the difference in mean gains. The results showed no significant advantage in favor of either plan. There was evidence, however, that although the single laboratory period saved time for the pupils, it entailed more work on the part of the teacher than did the double-period plan.

* Victor A. Sugar, An Investigation of the Relative Values of Single Laboratory Periods and Double Laboratory Periods in High-school Chemistry. Unpublished Study, University of Michigan, 1928.

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[1] In accordance with the criterion repeatedly stated and indicated by members of the N.A.R.S.T. in connection with their evaluations of the studies presented in this book, no title is included in this bibliography as a report of a research investigation unless it presents a statistical treatment of data obtained in an attempt to solve, by investigational techniques, a clearly stated or indicated problem.

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STUDY NO. 243

Survey Courses in the Natural Sciences

By Robert J. Havighurst*

Problem.—To determine the nature of college survey courses in the physical and biological sciences and "to point out the advantages and disadvantages which are attributed to them."

Method.—An analysis was made of the announcements of survey courses in science found in the catalogs of 64 liberal

* *The American Physics Teacher*, III (September, 1935), 97–101.

arts colleges, for the year 1935–36. Some comparisons were made with two earlier similar studies.

Findings and Conclusions.—1. "Survey courses are at present increasing in numbers." ". . . very few survey courses are more than two or three years old, and a considerable number of them are being given for the first time this year [1935]."

2. There are three types of survey courses: natural sciences, physical sciences, and biological sciences. A single survey course in natural sciences includes material from all the physical and biological sciences. "The various special sciences may be presented separately by specialists in the separate fields," or there may be integration of these materials.

3. "The typical natural-science survey course is a three-hour course which continues for two semesters." "Survey courses in physical or biological sciences usually carry two to four credits for two semesters. Thus . . . there is one group of colleges which devotes about six semester hours to general education in natural science, and another group which devotes 12 to 16 hours divided between courses in physical and biological science, to the same purpose."

4. When considered from the standpoint of emphasis, the science survey courses fall into four classes: comprehensive courses, selective courses, analytical courses, and descriptive courses. The majority of survey courses are comprehensive courses. These are encyclopedic in nature and give "an extensive survey of the topics within some broad field of knowledge." "Such courses may be divided into sections under the guidance of specialists in the separate subjects . . ." The tendency in these courses is to use with slight modification the form of organization of subject matter that is found in the separate subject fields.

5. "A selective course is one in which a small number of topics or principles form the framework, the subject matter pertaining to them being drawn from different science fields.

The principles may be either "interpretative generalizations" to distinguish them from "pure science generalizations which are designed to extend knowledge in the fields of natural science." "No attempt is made to 'cover the ground' of the various sciences. The subject matter of a selective course may be chosen largely on the basis of what seem to be the most pressing student needs and interests . . ." "The selective course is to be contrasted with the comprehensive course."

6. An analytical course is one that emphasizes such relationships as "those that exist between the facts and the generalizations of pure science; those that exist between pure and applied science, and those that exist between science and philosophy, religion, morals, economics, politics, and other aspects of human life." Such courses often contain considerable mathematics.

7. "The descriptive course is one that presents information without much attempt to show relationships. The comprehensive course which covers a great deal of ground in a small amount of time tends to be descriptive rather than analytical. Selective courses tend to be analytical, but some of them are descriptive. All courses are to some extent a mixture of both types . . ."

8. "There seems to be no accepted pattern for teaching a survey course. Usually lectures, demonstrations, and discussion groups are used. A few courses are taught entirely by lectures, and a few others entirely in small conference groups. In nearly all cases, each student has one teacher with whom he is in close contact for the duration of the course, no matter how many other teachers may come in for short periods of time." "Most comprehensive courses are taught by several specialists from different fields; . . . most selective courses are taught by a single teacher."

9. "Teachers of survey courses are practically unanimous in their desire to meet the students' need for concrete experience by the use of something besides books and lectures. A

fourth or a third of the physical and biological courses require laboratory work, though . . . the problems of a satisfactory use of the laboratory in connection with a survey course have not been solved. Demonstrations arranged so that a student can come into the laboratory and get a close, detailed view of important materials and processes" and a laboratory open to students who volunteer to come in and work on projects in which they are especially interested are two plans in use. Museums are used in connection with several courses as are also "large collections of slides" and "moving pictures."

STUDY NO. 244

A Survey of Generalized-science Courses in Institutions of Higher Education

By Morris Winokur*

Problem.—To determine the status of generalized science courses in colleges and universities.

Method.—A questionnaire designed to secure desired information concerning various aspects of generalized science was sent to 172 institutions. Replies were received from 144, or 84 per cent, of which 98, or 68 per cent, were offering such a course, and four, or 3 per cent, planned to do so.

Findings.—1. Generalized-science courses are offered in all parts of the country, including Hawaii, in liberal arts colleges and universities, teachers colleges, normal schools, and junior colleges.

2. The first of the colleges represented by the replies, to give such a course instituted it in 1919. The largest number instituted in any single year (41), were established in 1934; and the next largest (14), in 1927.

3. The reasons most often given for instituting the course were "felt need" (41); "state requirement" (22); "general

* *Science Education*, XX (October, 1936), 132–140.

education program (junior-college movement)" (21); "description at another institution" (15); and influence of University of Chicago (7), University of Minnesota (2), and University of California (1). Five other reasons were each cited by one or two institutions.

4. The names most frequently given the generalized-science course were Science Survey (32), Science, (19), General Science (17); Introduction to Science (9); and Science Orientation (5). Eight other names were each used in from one to four institutions.

5. Forty-seven institutions "offered a single generalized course over the entire area of natural science;" 20 had "generalized courses in physical science and a separate generalized course in biological science. Very few have either a generalized physical-science or a generalized biological-science course alone. A very frequent combination is a generalized course in physical science with some standard course in biology, such as Educational, Introductory, or Human Biology."

6. The most frequently mentioned objectives for the course were "To give the student a general knowledge of the subject matter of science" (54); "To acquaint the student with the main generalizations of science" (22); "To learn to understand the environment" (19); "To serve as an introduction enabling the selection of regular science courses" (14); "To understand the scientific method" (12); "To give the student an appreciation of the scientific attitude" (12); "To correlate the various fields of science" (11); "To acquaint the student with the technique of science" (10); "To show the student the influence of science as an element in civilization" (10); and "To provide the content for the teaching of general science." Thirty-four other objectives were each mentioned by from one to seven institutions.

7. In nearly half these institutions (47) the course was offered for one year; in 22 it was offered for one-half year; in 13, for two years; in 12, for two-thirds year; in five, for one-third

year; and in two others, for respectively three years and one and one-half years.

8. Most of these schools (51) scheduled the course for three hours per week; 19, for four hours; 17, for five hours; and six, for six hours. Respectively three, one, and two institutions scheduled the courses for two, seven, and nine hours per week.

9. The number of period-hours devoted to the course ranged from 30 to 360. Eighteen institutions devoted from 100 to 109 period-hours to the course; 14 devoted 50 to 59; and 12, 175 to 199. The range was from 30 to 39 (four schools) to 300 to 360 period-hours (four schools).

10. Most of the schools (54) presented the course by "lecture-discussion combination"; 15 employed "lecture plus recitation"; 10, "lecture only"; seven, "lecture plus laboratory"; six, "discussion only"; four, "lecture plus recitation plus laboratory"; and one "discussion plus laboratory."

11. Most of the schools (49) devoted three lecture hours per week to the course; 15 devoted two; 13 gave five; seven, none; seven gave four; six gave one; and one devoted six.

12. The modal number of recitation hours per week for the course was none (17 schools); 12 schools provided one; six provided two; four provided three; three provided four; one provided seven.

13. An overwhelming majority of these institutions (80) had no laboratory periods in connection with this course; seven devoted to it two laboratory periods per week; three provided one; four provided two; and three had respectively three, five, and six laboratory periods per week.

14. The largest number of schools (24) devoted all their periods assigned to the course to use of the demonstration method; 30 devoted one-third, and 13 one-half the assigned periods. Sixteen schools stated that they devoted "few" periods to demonstration; seven, three-fourths of their periods; and one school, none.

15. The ranges in numbers of hours devoted to the subject-matter areas, were respectively 0–40, (astronomy); 0–60

(geology); 0–80 (physics); 0–60 (chemistry); 0–165 (biology); and 0–55 hours (psychology). The modes were for astronomy 12; for geology (including meterology and geography) 18; for physics, 18; for chemistry, 18; and for biology, none (in 21 schools) and 54 (offered by 15 schools); and for psychology, none (in 69 schools); "in 10 institutions it [psychology] was treated only incidentally as part of the biological area . . ." With respect to total time allotment, "approximation seems to indicate that astronomy, geology, physics, and chemistry receive about equal attention, chemistry perhaps slightly more. Biology, if included in the course, takes up one-third to one-half the time. Relatively little time is devoted to psychology."

16. Other specialized areas offered outside the subject-matter areas of science included mathematics (6); history of science (3); scientific method (2); and teaching of science, library use, photography, and labor-saving devices (one each).

17. "Two-thirds of the colleges, 65 in number, now utilize the plan wherein one instructor remains with the class throughout the course or term. One third . . . (33) change instructors for different areas of subject matter. A few replies (seven) indicate that special lecturers are brought in for particular topics."

18. Of 278 instructors whose degrees were reported, "only 17 are limited to the baccalaureate degree. The others, 261 in number, have higher degrees, 100 having the master's degree, and 161 the doctorate. It must be noted, though, that the degrees are in many cases extraordinarily particularized."

19. Of 288 instructors (19 institutions not reporting), "only 28 devote their entire time to the course and 260 teach other subjects as well, usually the special science courses." Only five of the colleges have separate staffs for science survey, "while in 65 colleges it is the policy to assign the course as a part of the instructor's schedule."

20. Conservatively speaking, in 1936 about forty thousand students studied generalized science as a required course, and

about as many more elected it. In 46 schools the course was a requirement of all students. The number of students studying generalized science has been increasing from year to year.

21. "The degrees and diplomas for which the course is required vary considerably but most common are teaching certificates (38 schools), the B.A. degree (25 schools), the B.S. in Education (21 schools), the B.S. degree (8), the Junior College Diploma (7); and the A.A. (5). The course is required for six other degrees, each represented by one institution, and is not a requirement for any degree in 15 of the colleges.

22. The numbers of students in the lecture groups ranged from 10 in two colleges, to 360 in one. The modal number, 30, was found in 11 institutions.

23. The numbers of students in the recitation groups ranged from 15 in three institutions to 55 in one. The modal number, 30, was found in 10 institutions.

STUDY NO. 245

Survey Courses in the Natural Sciences

By Clarence M. Pruitt*

Problem.—To determine the existing practices with respect to survey courses in science in liberal arts, and teachers colleges.

Method.—A questionnaire, embodying 10 questions relative to practices with respect to survey courses in science, was sent to 128 liberal arts, and state teachers colleges. Replies were received from 58 liberal arts colleges, and 53 state teachers colleges, of which 23 liberal arts, and 33 teachers colleges offered survey courses and hence furnished the desired information concerning them.

Findings.—The responses of the institutions offering survey courses in science are summarized in Table LXXXXVIII.

* *Science Education*, XXI (February, 1937), 10–16.

TABLE LXXXXVIII

PRACTICES WITH RESPECT TO SURVEY COURSES OF SCIENCE IN TWENTY-THREE LIBERAL ARTS COLLEGES AND THIRTY-THREE STATE TEACHERS COLLEGES

Question	Liberal arts colleges		Teachers colleges	
	Number responding		Number responding	
	No	Yes	No	Yes
Is the course elective for Freshmen?	12	11	25	7
Is the course required for Freshmen?	11	12	7	25
Is the course elective for Upperclassmen?	9	10	22	10
Are non-science majors required to take additional science courses?	17	2	22	5
Does the course count as a part of the major or minor for those majoring or minoring in science?	16	4	17	12
Do the same teachers teach both the biological- and physical-science phases?	14	7	28	4
Do you have individual student laboratory work in connection with the course?	18	2	28	4
Do you use your own syllabus?	6	15	14	16
Do you use a textbook in the course?	13	7	23	8
	Number of hours		Number of hours	
	Mean	Range	Mean	Range
How many hours credit does the college give?	8	3–12	7+	3–10

STUDY NO. 246

An Analysis and Evaluation of Courses in the Teaching of Science

By Henry H. R. Brechbill*

UNIT I

Problem.—To determine the extent to which courses in the teaching of science, or of any particular science, are offered in college and university curricula for the training of teachers of science.

Method.—During 1932 an examination was made of the latest available catalogs of 138 colleges and universities (exclusive of "teachers colleges and strictly technical institutions") enrolling 500 or more students, and offering curricula both in arts and sciences and in education. These institutions were divided into seven groups according to size, and a determination was made of the number in each group offering (1) no courses in the teaching of any particular subjects; (2) courses in the teaching of some particular subject but not science; (3) no course in the teaching of science; and (4) one or more courses in the teaching of science. An analysis was made to determine both the field covered by each course offered in the teaching of science and the department in which each of the courses was given. The results of this analysis were checked against information supplied by a large number

* Dissertation for the degree of Doctor of Philosophy, George Washington University, 1933. A report of the first unit of this study appears under the title, "Status of College and University Offerings in the Teaching of Science," in *Science Education*, XVIII and XIX (December, 1934 and April, 1935), 221–225 and 60–65; and a report of the second unit appears as "The Value to Science Teachers of Courses in the Teaching of Science," in *Educational Administration and Supervision*, XX (October, 1934), 541–547. A summary of this investigation appears in *The George Washington University Bulletin—Summaries of Doctoral Theses* (Washington, D. C.: George Washington University, 1934), 47–54.

of the instructors offering these courses, to whom the investigator had sent letters of inquiry.

Findings and Conclusions.—1. A course in some phase of the teaching of science is offered by 84 of these 138 colleges and universities.

2. Courses in the teaching of science are offered much more frequently in large than in small institutions.

3. "Of 106 colleges and universities which offer courses in the teaching of particular subjects, 19 per cent omit science teaching."

4. The 150 courses in the teaching of science found in these institutions were divided as follows among the various fields: science in general (38), botany (10), zoology (9), physiology (2), biology (27), chemistry (21), physics (19), physics and chemistry (11), general science (11), geography (2); all courses devoted to the teaching of biological science (48); all courses devoted to the teaching of physical science (51).

5. "Many courses in science teaching are directed towards special fields of science that possess no separate identity in the usual secondary course of study, e.g., zoology."

6. "Courses in science teaching which are undifferentiated as to special science field are taught more frequently by instructors in education departments."

7. "Courses in science teaching are taught by instructors in science departments slightly more frequently than by specialists in education. This is not true among the largest institutions."

8. "The average credit allowance for courses in science teaching is 2.3 semester hours, an amount much lower than that recommended by expert opinion in this field, and much too small to afford opportunity for the treatment of the topics which teachers report to be of high value," as indicated in the findings of the second unit of this investigation.

9. ". . . all . . . expressions of an attitude definitely out of sympathy with the study of education emanated from

instructors giving a course in the teaching of one of the sciences and belonging to a subject-matter department."

10. While there is a wide variety of titles for courses in the teaching of science, that "which is found most frequently in use and seems preferable is: 'The Teaching of Science' or 'The Teaching of Chemistry' (or other special science)."

11. Of the 150 courses, 63.3 per cent were "teaching" courses in which attention was called to the pedagogy of the subject but in which no particular phase of it was emphasized; 17.3 were "methods courses which emphasized a limited aspect of the problem of teaching not in harmony with the variety of content supported by the findings of [the second unit of] this study"; 8.7 per cent are courses involving method, content, and organization; and 10.7 put the emphasis on science content.

UNIT II

Problem.—To determine what topics are treated in courses in the teaching of science and to determine the relative values of these topics to teachers of science.

Method.—An analysis was made of eight books dealing with the teaching of science, all published since 1912. The entire contents of the eight books were tabulated under 12 main divisions: "History and Status of Science"; "History and Status of Science Teaching"; "The Nature of Science (Scientific Method) and Its Relation to Life"; "Objectives (Aims, Values, Purposes) of Science Teaching"; "Selection and Organization of Subject Matter"; "Methods of Teaching Science"; "Class Management"; "The Laboratory: Its Equipment and Supplies"; "Testing"; "The Teacher of Science"; "Printed Sources of Information"; and "The Teaching of Sciences Other Than General Science, Biology, Physics, and Chemistry." Under these 12 principal divisions were subsumed 165 topics, including every subject which

received in any of the eight books, as much as one-fourth page of discussion." ". . . each of the eight books was read carefully and the content of each page or portion of a page was assigned to the appropriate topic . . . If the content of any quarter page could not properly be identified with any listed topic a new topic was added." The resulting list was submitted to eight graduate students in education, each of whom rechecked one book against it, adding such topics as he thought should be added. These added topics totaled 15. Twelve more topics were contributed by "15 instructors of courses in some phase of science teaching in institutions selected at random," who were asked to add topics treated in their courses but not included in the list. Additional topics sufficient to raise the total to 203 were added from the Commonwealth Teacher-training Study.

The check list was submitted to 487 teachers of science, chiefly in Maryland, Pennsylvania, Virginia, West Virginia, Ohio, and the District of Columbia. These teachers were given the following instructions: Check each topic (1) "whose treatment in your training courses you can remember; (2) whose treatment you have found *practically useful;* (3) whose treatment you have found *useful* in your *thinking;* (4) which you think should be *included* in the *training course;* and (5) which you think should be *excluded* from the *training course.*" The teachers were also asked to indicate whether they had ever studied a course in the teaching of science, and if so, to give the name of the course, and to indicate the college year (Junior, Senior, or Graduate), in which they studied it. They were further asked to list in descending order of relative value to them, four professional education courses exclusive of the teaching of science, which they had studied, and then to indicate where in this ranking they thought the course they had had in the teaching of science belonged.

From the 200 teachers returning usable replies, 16 were selected as a "jury of reference," who were certified by their

"ranking educational superiors as being teachers of marked ability, professional attitude, and sound judgment."

The same check list which was submitted to the teachers, was also sent to 99 college and university instructors who give courses in various phases of the teaching of science. They were asked (1) to check the topics which they actually included in the courses they gave and to indicate both (2) those which they expected and intended to be of practical value to their students when the latter became teachers; and (3) those which they expected and intended to be of help to their students in their educational thinking, that is, which they expected to possess indirect value; (4) to indicate their opinions regarding the desirability of including each of the topics in the course in the teaching of science, whether they actually included the topic in the course or not; (5) to add additional topics which they discussed in the course or which they thought should be included in it; and (6) to add any comments they cared to make concerning the special methods courses for high-school science teachers. Forty-four usable replies were received.

An "index of relative prominence for each topic" was obtained by first computing for each topic (1) the percentage of all the text books which included a discussion of it, (2) "the percentage of instructors who included it in their courses," and (3) "the percentage of teachers who remembered it"; and by then adding to the sum of the second and third of these percentages, 10 times the first percentage. The "reliability of ranking" was also determined by separating the 200 lists filled in by teachers into two sets at random and by tabulating each set separately for "includes." The Spearman *rho* formula[1] was used and the S.E. was computed.[2] Similarly rank order correlations were computed between "teacher

[1] $\rho = 1 - \frac{6\Sigma D^2}{N(N^2 - 1)}$.

[2] $\sigma_\rho = \frac{1.047(1 - \rho^2)}{\sqrt{N}}$.

approval" and "prominence," and between "teachers' includes" and the "jury's includes."

The relative importance of the activities in the list was determined by comparing the list with that in the report of the *Commonwealth Teacher Training Study*.

Findings and Conclusions.—1. Courses in science teaching have been taken by almost 75 per cent of these science teachers.

2. "According to the judgment of science teachers, their most valuable course in education was the course in the teaching of science."

3. "The topics of a course in science teaching prove more helpful to teachers in their practical teaching than in their educational thinking."

4. "A positive correlation of .577 between the order of science teaching topics in *prominence* in existing courses on the one hand and in *teacher approval* on the other, indicates opportunity for improvement in existing courses."

5. "Topics dealing with aims and objectives of science teaching; selection and organization of subject matter; methods of teaching; printed sources of information such as textbooks, periodicals, etc.; testing; and personal qualifications of science teachers all rate high in the estimation of teachers."

6. "Historical topics and those descriptive of existing conditions in science teaching are rated low by teachers."

7. "The inclusion of specific content of high-school science courses does not appeal favorably to most teachers."

8. "Topics dealing with class management and general school activities, because of the importance and frequency of the teacher activities to which they are related, seem to be entitled to some emphasis in this professional course which approaches nearer to the actual vocational problems of the teacher than any other course except practice teaching."

STUDY NO. 247

An Experimental Study at New York State Teachers College at Buffalo to Determine a Science Program for the Education of Elementary Classroom Teachers

By Anna M. Gemmill*

UNIT I

Problem.—To determine the nature of the training in science afforded elementary teachers.

Method.—An analysis was made of the science taught and the "science requirements in 16 representative institutions in 10 states in various parts of the country." Tabulations were made of the numbers, titles, distributions and frequencies by subject of the various courses taught in nature study, general science, astronomy, chemistry, physics, biology, geology, zoology or botany, and in the teaching of science; in the amount of "science required but not specifically designated," of the distribution and frequency by subject of titles of required and elective courses in science offered in these institutions.

A further study was made of the preparation in the subject matter of science secured by 398 prospective elementary teachers who had graduated during the preceding five years from nine teachers colleges selected at random.

Findings.—1. Of the 238 courses in science offered in the institutions studied, 68.5 per cent were biological in nature; 28.8 per cent were studied for a 12-week period; and 72.6 per cent "consisted of a single course in science of one semester or less in length."

* Dissertation for the degree of Doctor of Philosophy. Contributions to Education, No. 715. New York: Teachers College, Columbia University, 1937. Only those portions of this dissertation which report statistical procedures are here digested.

2. Of the students, 50.75 per cent had taken work in only one field of science; and of this group 63.1 per cent had only one course in the field; and for 63.1 per cent of the group the field was biological science.

3. "Of the 166 science sequences offered, almost 84 per cent were of a biological nature."

4. "Practically no selection is being made from the mass of electives."

UNIT II

Problem.—To determine the training in science which elementary teachers should receive while in teacher-training institutions.

Method.—Following a survey of the literature pertaining to the problem, the investigator made an elaborate analysis of the knowledges, skills, and appreciations with respect to the professional, the civic, the recreational and the aesthetic points of view, which the teacher of elementary science should have as a result of her training in the teachers college.

"When this analysis had been made in tentative form, it was checked and criticised by other members of the Science Department of the State Teachers College at Buffalo. Additional qualities were added and different wording, in some instances, was suggested." The resulting outline received further criticism from members of both the Department of Education and the science staff of the State Teachers College at Buffalo before it reached its final form.

A study of this outline led to the formulation of three assumptions:

". . . a student teacher can attain progressive growth in scientific knowledge of the world and its life."

". . . a student teacher can develop ability to analyze the phenomena of natural science, to enlarge science understandings, and finally to arrive at correct explanations of occurrences."

". . . a student teacher can develop ability to help pupils to apply the experiences and principles of science to life situations within the range of the pupils' own experiences."

On the basis of these assumptions a tentative survey course was constructed emphasizing generalizations or principles of science selected from a study by Craig,[1] from an unpublished study by Powers, and from Part I of the Thirty-first Yearbook of the National Society for the Study of Education.[2] These selected generalizations were "broken down into teaching material by the method used by Billig."[3] This course was then taught to two Freshman classes each of 40 students in the New York State Teachers College at Buffalo. On the basis of the results of this teaching, a final outline was constructed of which the major points were generalizations which were to be developed with various factual materials. This course was refined through two additional years of teaching. During the third year the Co-operative Tests in General Science were administered to 114 Freshmen before any instruction in the course was given and again at the end of the course. The significance of the resulting scores before and after teaching was determined by dividing the difference in mean scores by the P.E. difference of these mean scores.

Findings.—(1) The results of the testing indicated 97 chances out of 100 that the difference resulting from teaching the outline was a true one greater than zero.

A sample of the course outline follows:

MAN'S PLACE IN SPACE

I. Space is vast

A. The circumference of the universe is so great that even the smallest measurement assigned is beyond the imagination of man

[1] *Investigations in the Teaching of Science*, Vol. II, pp. 40–52.

[2] *A Program for Teaching Science*, Thirty-first Yearbook, National Society for the Study of Education (Bloomington, Illinois: Public School Publishing Company, 1932).

[3] *Investigations in the Teaching of Science*, Vol. II, pp. 374–380.

B. The astronomical units used to measure the colossal distances of space must be much larger than terrestrial units

C. Using the light year as a unit of measure, the light from the sun reaches the earth in about eight minutes, from the nearest star in 4.27 light years, and from the more distant stars in many thousands of years

II. The earth is a small part of our galaxy or universe

A. The sun, planets, satellites, comets, and meteors make up the solar system, which, large as it is, is but a tiny dot in the universe of stars

B. The planets are similar in some respects but very unlike in other characteristics

STUDY NO. 248

The In-service Education of Teachers of Ninth-year Science in New York State Outside of New York City

By John Farl Hummer*

Problem.—To determine (1) the qualifications of the teachers of general science and biology and the nature of their teaching assignments; (2) what knowledges and skills these teachers use in their daily work; (3) in which of these knowledges and skills they believe further education is needed; and (4) what they consider the most effective means for supplying this needed education.

A questionnaire of two parts was prepared: Part I sought information regarding the character of the organization of the school in which the teacher was employed, the number and sizes of her classes, the subjects she taught and how long she had taught each, the character of each group she taught, and her pre-service education. Part II sought reactions to a list "of 101 knowledges and skills believed to be more or less

* Unpublished dissertation for the degree of Doctor of Philosophy, New York University, 1934.

essential in teaching ninth-year science." This list had been obtained from Charter's *Commonwealth Study List of Teacher Activities*, from courses of study in general science and biology, from textbooks in these two subjects, from conferences with teachers, and from the investigator's experience as a teacher of science. Before this list was included in the questionnaire it was submitted to a number of experts in the teaching of science for their opinions with respect to its adequacy, and was approved by them. This questionnaire was sent to more than eleven hundred teachers of ninth-year science (elementary biology and general science) in schools in New York State outside New York City. These teachers were asked to indicate which of the knowledges and skills they used in their teaching "Frequently"; which, "Occasionally"; and which, "Rarely or Never"; and to check those items with respect to which they thought there was a general need for further education. Responses were received from 544 teachers.

Findings.—1. Of the entire group, 38.4 per cent had taught 0–3 years; 20.4 per cent, 4–6 years; 19.1 per cent, 7–10 years; 14.7 per cent, 11–20 years; and 7.4 per cent, over 20 years.

2. The less experienced teachers were found in largest proportions in the smaller communities, where they taught a larger number of different subjects per teacher (a few taught four different subjects), but had smaller classes than the teachers in the larger communities.

3. The teaching assignments of these teachers most frequently combined science with mathematics, commercial subjects, social studies, or physical education.

4. "The largest proportion of college degrees was reported by the youngest group of teachers."

5. "Biology and chemistry were the leading majors. Sixty-eight per cent of the respondents were science majors."

6. "The youngest group of teachers have taken more in-service education, in proportion to the time available, than have older teachers. More of these teachers have taken sum-

mer school and residence courses than have taken extension courses."

7. Length of experience or size of school system "has little effect upon the knowledges and skills used by these teachers in their daily teaching activities."

8. The most frequently used knowledges are knowledge of the laws of healthy living, of the subject matter of elementary biology, of the accepted objectives of general science teaching, of the elements of a good assignment, and of the content of the *State Course of Study*.

9. The most frequently employed skills are skill in planning work to meet objectives, in selecting and organizing subject matter to meet objectives, in relating science to living, in teaching pupils to draw accurate conclusions from evidence, in demonstrating experiments, in interesting pupils in general science, in sustaining pupil interest, in teaching pupils to observe accurately, in making good assignments, in using class time effectively, in making blackboard diagrams, and in teaching pupils to make accurate diagrams.

10. The greatest need was "for further education in the fields of subject matter and objectives." "Preparation seems to have been more adequate in elementary biology, physiography, and chemistry than in physics, geology, astronomy, and bacteriology."

11. There was need for help in such methods of teaching science as would assist teachers (1) to make science both function in the lives of the children and meet the needs of individual children; (2) to integrate science with other school subjects; and (3) to teach children how to study.

12. The most effective in-service education was provided by further training in the subject matter and the objectives of science, in methods of teaching science, and in general classroom methods; and by study courses, reading, observations of teaching, teachers' meetings, and visits to libraries, museums and exhibits.

STUDY NO. 249

Activity Analysis as a Basis for Supervision in General Science

By Edith M. Selberg*

Problem.—To analyze the activities of student-teachers in classes of general science "in order to discover: (1) the common errors made by beginning teachers in science, (2) the more difficult elements of teaching in general science, and (3) the reasons why certain teaching activities were difficult."

Method.—"The supervisor recorded the errors made by the student-teachers during the actual classroom teaching. The student-teacher was asked to tabulate all the activities actually engaged in for a period of two weeks, such as grading papers, planning demonstration lessons, planning a test, and many others. Then, through a personal interview with the student-teacher, the supervisor was able to learn and record a reason why certain activities were more difficult than others. Through an analysis and comparison of the data thus obtained [from 21 student-teachers], ideas were arrived at as to the relative degree of difficulty of the various teaching activities and as to the amount of attention and emphasis which should be given to each."

Findings.—1. "Certain teaching activities are very difficult for beginning teachers and require careful attention in the supervisory program."

The list of errors revealed by the analysis follows:

Errors of Beginning Teachers in General Science

Errors in Schoolroom Mechanics

Fails to regulate light and ventilation
Fails to use time-saving devices in distributing materials
Does not provide time to put away materials

* *Science Education*, XVI (February, 1932), 188–191.

Fails to have proper equipment ready for use
Disregards his own posture
Lack of order in passing from room to room
Fails to quiet pupils upon entering the room

Errors in Recitation and Directed Study

Too much teacher activity
Fails to apply the scientific principles to a practical situation
Fails to drill on scientific words and phrases
Assignments inadequate due to incompleteness and indefiniteness
Directions poorly given
Answers questions that pupils can answer
Questions not worded clearly and concisely
Questions do not focus upon the principles of the unit
Fails to emphasize the elements of problem solving
Students not made to evaluate own statements
Does not insist upon reasonably good English
Pupil's voice audible to teacher only
Teacher's voice indistinct
Lack of illustrations to clarify principles
Fails to see that language is confusing to the class
Fails to ask questions which require reflective thinking
Fails to use blackboard to good advantage
Fails to provide supplementary material
Fails to locate pupils' errors in solving problems
Fails to stimulate disinterested student
Fails to provide for individual differences
Fails to guide pupils in the analysis of problems

Errors in Testing

Fails to select important concepts for testing
Fails to test for the elements of problem solving
Statements ambiguous

2. "Some of the activities especially difficult, as revealed by personal interviews, and some of the reasons for each difficulty, as stated by students are:

The Preparation of the Daily Lesson.—The student-teachers found difficulty in picking out the essential point; in "putting the subject matter across to pupils"; in formulating questions; in providing for individual differences; in formulating drill questions; and in devising study helps.

Additional difficulties were occasioned by inadequate background of subject matter; by uncertainty with respect to what technique to try; and by lack of confidence.

Questioning.—The student-teachers found difficulty in formulating questions stimulating reflective thinking rather than mere recall.

Conducting the Lesson.—The student-teachers found difficulty in "thinking on their feet"; in talking to a group; in making up their minds quickly when problems arose; and in supervising the great number of pupil activities necessary under the individual instruction plan. Additional difficulties were occasioned by inadequate background of subject matter.

Making Assignments.—The student-teachers encountered difficulty in giving definite directions; in teaching pupils how to study; and in foreseeing pupil difficulties.

Preparation of Tests.—The student-teachers found difficulty in determining questions that test all degrees of ability; in determining the right concepts to be tested; and in determining the right kinds of tests.

Giving Demonstrations.—The student-teachers encountered difficulty in determining how the application is to be made; in determining the type of demonstration for the type of subject matter; and in determining the questions which will set up a hypothesis in the student's mind.

Determining Marks.—The student-teachers found difficulty in keeping the subjective element out of marking; in deciding the best method of marking; and in marking as rigorously as the evidence of achievement indicated.

3. "Some of the frequent errors arise because the young teacher does not understand or is unable to apply certain pedagogical principles and theories, such as:

That the elements of problem solving must be emphasized in every phase of science teaching;

That a scientific principle, or generalization, is not learned until the pupil can apply it to a practical situation;

That students should evaluate their own statements;

That the *skill* to be developed in science is reflective thinking;

That through individualized instruction pupils learn correct study habits, learn to solve individual problems, and proceed to learn at a rate which is equal to their abilities."

STUDY NO. 250

Concomitant Learning in Human Biology

By Palmer O. Johnson*

Problem.—"To obtain a measure of some of the outcomes other than specific learning which might grow out of a course in Human Biology."

Method.—An examination was prepared consisting of "100 true-false statements of common beliefs regarding health and disease, supplemented by a considerable number of statements of claims made relative to the effectiveness of certain home remedies or commercial preparations." "The examination was validated by securing the independent judgments of three authorities in the fields of physiology and medicine relative to the scientific evidence now available, upon which might be based the truth or falsity of a given statement. No statement was introduced into the examination upon which there was not unanimous agreement on the part of the judges. In addition, a graduate student, trained in the field of physiology and medicine attended all class meetings and kept a complete record of the materials presented. No statements identical with materials given in the lectures or in other materials of instruction were introduced. An analysis was made, as well, of the content of other courses taken concurrently by the students to note that the materials in the examination had not been given in such sources." The reliability of the examination was .85 ± .01.

Examples of the test items follow:

The majority of people troubled with obesity have glandular disorders which can be cured by medicines.

A mother has a prenatal influence on an expected child.

Boils are an indication that the blood is purifying itself from within.

* *Science Education*, XX (February, 1936), 11–17.

The eating of red meat causes high blood pressure.
A congenital disease is inherited.

During the Spring Quarter of the year 1933–34, this examination was administered to 142 students, both preceding, and three months later following, instruction in a course in Human Biology in the General College of the University of Minnesota. The data were given an elaborate statistical analysis which involved "a comparison of the types of distribution of scores on the initial and terminal examination and the significance of the differences between the mean values and the variances of the two."

Findings and Conclusion.—". . . there was not only a significant difference between the means but also in the variances of the students' scores previous and subsequent to instruction. It may be concluded, therefore, that there has been a significant change in the reactions of students towards common beliefs regarding health and disease, and towards the claims made relative to the effectiveness of certain home remedies and commercial preparations, over a three months' period during which they were given instruction in human biology."

STUDY NO. 251

A Study of the Effect of a Course in High-school Biology on Performance in College Biology

By Bert Cunningham*

UNIT I

Problem.—To compare the relative achievements in zoology and botany of two groups of college students, those who have studied biology in high schools and those who have not.

Method.—A comparison was made of the marks of two groups of students in Duke University. One group, which

* *School Science and Mathematics*, XXXIV (June, 1934), 578–588.

included 426 students of zoology for the years 1931–33 inclusive and 225 students of botany for the years 1932–33, had all studied biology before entering college; the other group, which included respectively 247 and 126 students from the same classes in zoology and botany as those from which the first group had been drawn, had not studied biology in high school. The percentages of each group who had earned the marks of A, B, C, D, and F were computed and compared.

Findings.—1. The percentages of students of zoology receiving marks of A, B, and C in the group who had studied biology in high school were considerably larger than were the percentages of those earning these marks in the group who had not. The corresponding superiority of the students of botany who had studied biology in high school, over those who had not, was less marked.

2. The fact that the percentages of failures were so nearly the same for those who had studied biology in high school and those who had not, "indicated that some schools are giving exceedingly poor courses in biology."

UNIT II

Problem.—To determine whether the type of laboratory work accompanying high-school courses in biology affects college performance in zoology and botany.

Method.—Comparisons of achievement, similar to those made in Unit I, were made for three groups of students of zoology: (1) 118 who in their high-school courses in biology had had only individual laboratory work; (2) 86 who had performed their laboratory exercises in high-school biology in groups of two to four; and (3) 211, who in their high-school courses in biology had had only demonstration experiments. Similar comparisons were made for three corresponding groups of respectively 41, 85, and 95 students of botany.

Findings.—1. The percentages of those botany students earning marks of A and B in the group who had had individual

laboratory work in their high-school biology courses, were considerably greater than the percentages of those earning these same marks in either the group who had done their laboratory work in pairs or in small groups, or who had had only demonstration work.[1] The percentages of those botany students earning these marks in the group who had had only demonstration experiments were greater than the percentages of those who had worked in pairs or in small groups.

2. With respect to the zoology students, the superiority of none of these groups over the others was clearly marked, though the percentages of the students earning marks of D and F were much smaller for the students of the first group than for those of either of the other two.

UNIT III

Problem.—To compare the achievements of "pre-medic" students in classes of college zoology with the achievements of the other students in the same classes.

Method.—A comparison, similar to that of the preceding units, was made of the achievements of 310 pre-medical students with those of 364 other students in the same classes of college zoology.

Findings.—The pre-medical students received more than three times as large a percentage of marks of A, and about 10 per cent more marks of B than did the other students.

UNIT IV

Problem.—To compare the achievements in zoology and botany of students entering Duke University from Northern secondary schools with those of students entering from Southern secondary schools.

Method.—Several comparisons, similar to those of the preceding units, were made: (1) of achievements in zoology of

[1] Compare with results secured with groups-of-two by Carpenter, *Investigations in the Teaching of Science*, Vol. II, pp. 284–288.

337 students entering Duke University from Northern secondary schools with those of 330 students entering that institution from Southern secondary schools; (2) of achievements in zoology of 1,420 students entering from New York, Pennsylvania, and New Jersey with those of 144 students entering from North Carolina; (3) of achievements in zoology of 31 students from New York, and also of 36 from Pennsylvania, with those of 35 from North Carolina; and (4) of achievements in botany of 81 students from Northern secondary schools with those of 90 students from Southern secondary schools.

Findings.—1. In the total group the percentages of the students from the South who received marks of A and B in zoology were higher than those of the students from the North who earned these marks, but the percentage of these Southern students who received a mark of F was higher than that of the Northern students.

2. The group from New York, Pennsylvania, and New Jersey scored higher percentages of A and C marks and a much lower percentage of F marks than did the group from North Carolina. In the next comparison, however, the group from North Carolina received a considerably higher percentage of A, B, and C marks than did the group from either New York or Pennsylvania.

3. With respect to achievement in botany, students from the North received three marks of A and 13 of B, as compared with one mark of A and 24 of B for the Southern group. The numbers of students receiving marks of C, D, and F were the same for both groups.

UNIT V

Problem.—To compare achievement in zoology and in botany, of Freshmen, Sophomores, Juniors, and Seniors.

Method.—A comparison, similar to those of the preceding units, was made of the achievements in zoology of groups

composed respectively of 439 Freshmen, 163 Sophomores, 54 Juniors, and nine Seniors.

Findings.—Most of the students of each of the four college years earned marks of C. No marked superiority was apparent for the students of one year over those of the others.

UNIT VI

Problem.—To compare the achievements of men students in zoology and botany with those of women students in these subjects.

Method.—Comparisons, similar to those of the preceding units, were made of the percentages of 487 men and of 210 women who studied zoology in Duke University during a three-year period, and of 173 men and 191 women who studied botany in the same institution during a two-year period.

Findings.—Higher percentages of men than of women earned marks of A, B, and C in zoology; the opposite was true with respect to botany.

Conclusions.—1. "A high-school course in biology does have a beneficial effect on one's performance in college zoology, provided the course has been pursued in our better schools. The beneficial effect on botany, while present, is not so evident . . ."

2. "Individual laboratory work is preferable to demonstration" while laboratory experimentation by small groups of students is "less desirable than either individual or demonstration, doubtless due to the fact that in many cases the grouping of four or more is a make-shift procedure while for demonstration more serious preparation is made by the teacher."

3. "Southern schools, while furnishing more failures, still furnish their full quota of better students. This is true of North Carolina schools, specifically."

4. "As one might expect, professional outlook affects college performance in zoology favorably."

5. "The relative performances of men and women in zoology or botany do not seem to differ materially, other things being equal."

STUDY NO. 252

A Comparative Study of the Effectiveness of Student-made, and Prepared Drawings in College Laboratory Work in Biology

By Morris L. Alpern*

Problem.—To determine the relative values, with respect to the acquisition and retention of factual knowledge, of two methods of laboratory procedure: (1) having the students make drawings from their observations of the specimen; and (2) having them record their observations on drawings already prepared.

Method.—Students enrolled in the second semester course of elementary biology at the College of the City of New York were divided into an experimental (X-) and a control (C-) group, each of eight sections, totaling respectively 109 and 103 students. The two groups were equated on the following bases: (1) intelligence as measured by scores on the Thurstone Psychological Examination; (2) college class; (3) registration for science or non-science degree; (4) intention to major in biology; (5) number of terms' work in biology studied in high school; (6) number of terms of physics studied at the College; (7) number of terms of chemistry studied at the College; (8) number of terms of science survey; and (9) mark in Biology I. "Both groups were approximately equivalent for *all* of the above traits."

The investigation occupied a three-week period during which the laboratory study was devoted to the dissection of the frog. The classes met for one four-hour laboratory period

* *Science Education*, XX (February, 1936), 24–30.

per week. The laboratory procedures consisted of (1) an introductory talk in which the instructor explained the purpose of the exercise, the technique of dissections, the sections of the laboratory manual to be followed, and drawings to be made; (2) the laboratory exercises proper, in which during the major portion of the period, the students dissected their own specimens, made observations and used supplementary aids such as charts, reference books, prepared dissections, and the like; and (3) recitation on the work taken up in the laboratory. Every effort was made to keep constant and unvarying all factors and conditions of the experiment except the experimental factor (the drawings).

The entire experiment involved the making or the labeling of seven drawings. The drawings made by the C-group "included both the representative and the analytic types." The students were required to label the various structures mentioned in the manual. The drawings used by the X-group were selected from various sources to "fulfill the requirements of the drawings called for in the laboratory manual." They were copied or enlarged, then mimeographed. "While making his observations, the student was required to label the structures indicated on the prepared drawings."

A final test, two forms of which were constructed to administer on successive days, was administered at the end of the experimental period; and several weeks later a second test, likewise constructed in two forms, was applied to measure retention. Each form of the final test consisted of 55 new-type items selected by the members of the department of biology and the author, and designed to measure (1) names of structural parts; (2) interpretation of structure in terms of its function; (3) physiology of parts based upon anatomical relationships; and (4) knowledge of habits of the living organisms. The items of the retention test were selected from those of the final tests. "Some measure of the validity of the tests used was secured by the correlation, based upon 130 cases, obtained

between initial laboratory grades given by the instructor previous to the beginning of the experiment, and the final laboratory grades." The correlation, while low, was positive, and "on the basis of the criteria set up for the selection of items, the test was assumed to be sufficiently valid to warrant the conclusions drawn." ". . . the reliability of half the test was measured, and then by Spearman's Formula, the reliability of the whole test was found." The reliabilities of the two forms of the final test were thus found to be respectively .52 ± .05 and .51 ± .05, and of one form of the tests for permanent retention, .69 ± .03. "The 'critical ratio,' the difference in obtained means divided by the standard error[1] of the difference, was computed in each case in order to determine the significance of the obtained difference."

A further comparison was made with two equated groups composed of students rating above the 50-percentile point on intelligence, and on achievement as measured by the final test. Four other comparisons were made between the students of the X- and C-groups who, in Biology I, had received marks of respectively A, B, C, and D.

"To measure permanent retention, two groups of students, 71 in the C- and 77 in the X-group, were given a short test three weeks after the completion of the work on the frog."

Conclusions.[2]—1. "The procedure of labeling prepared drawings and the procedure of making original drawings are equally effective with regard to the student's ability to acquire and remember factual information from his laboratory observations."

2. "The two methods were equally effective at all levels of student ability."

[1] σ Diff. $= \sqrt{\left(\frac{\sigma_1^2}{N_1} + \frac{\sigma_2^2}{N_2}\right)(1 - r^2)}$.

[2] Compare these conclusions with those of Ayer, *Investigations in the Teaching of Science*, Vol. I, pp. 37–39; and of Bellew, Taylor, Colton, and Baird, Vol. II, pp. 195–199, 198, 199, and 202–207, respectively.

3. "It requires less time to make observations and label prepared drawings than it does to observe and make original drawings."

4. "The prepared-drawing procedure is more economical, and hence more effective, since it requires less time to be spent in drawing, and allows more time for observation and other laboratory activities. It is presumed that this time saved may be used to develop the more valuable outcomes of laboratory work."

5. "It is suggested that the prepared drawing replace the student drawing especially where the drawing is too difficult or is of the representative type."

STUDY NO. 253

Achievement in General Chemistry as It Is Related to Certain Learning Abilities

By Willis Joseph Bray*

Problem.—To determine the relationships of reading ability, knowledge of chemical vocabulary, ability to solve problems, and intelligence to achievement in general chemistry; and of intelligence and reading ability to teachers' marks.

Method.—The investigator first constructed an A and a B form of each of five tests. The first of these, The Expositive Reading Test, was a test of reading comprehension in which the pupils selected from among 40 multiple-response items, those facts which appeared earlier in paragraphs taken from textbooks of college chemistry.

* Dissertation for the degree of Doctor of Philosophy, University of Missouri. Published as a Bulletin of the Northeast Missouri State Teachers College, Kirksville, Missouri, Vol. XXXI, No. 6 (July, 1931). A report of this study appears under this same title in *Science Education*, XVI (December, 1931), 149–162; and under the title of "A Study of Achievements of Students of General Chemistry," in *School Science and Mathematics*, XXXII (January, 1932), 19–29.

The second, The Chemistry Vocabulary Test, consisted of 30 technical words selected "on the basis of the author's experience and judgment as to which constitute really key words in the study of general chemistry," from the Pressey[1] list of chemical terms. The subjects were directed to select in each multiple-response item the one of five choices "which indicated the meaning of the term as used in chemical literature."

The third, The Reading for Directions Test, was constructed from typical directions for experiments appearing in laboratory manuals of general chemistry. The student was directed to indicate, by correctly marking multiple-response items, "the successive steps to be carried out as given in the reading selections."

The fourth, and fifth tests were combined. These were The Test of Ability to Select the Steps Necessary to the Solving of a Chemical Laboratory Problem, and The Test of Ability to Rank the Steps That Are Necessary to the Solution of a Chemical Laboratory Problem. In each of six problems "the student was asked to indicate the steps that would have to be carried out in solving the problem, by encircling the number which stood before each of the steps selected." "After the correct steps had been thus marked, the student was asked to indicate in blank spaces to the right of the statements, the order in which these steps should be carried out."

Both forms of all five of these tests were checked for reliability by employing the data secured by administering the tests to typical groups in courses in general college chemistry and were revised when necessary, until a satisfactory degree of reliability was obtained.

The subjects of the main investigation were approximately three hundred twenty-five students who were enrolled in beginning general-chemistry classes in four state teachers

[1] Luella C. Pressey, *The Technical Vocabularies of the Public School Subjects*, No. 8 (Bloomington, Illinois: Public School Publishing Company, 1924).

colleges and one "standard arts college" in "widely separated sections" of Missouri. A study of age, sex, nationality, occupation of parents, year in college, and intelligence of these subjects indicated that the group was "typical of general chemistry students in colleges."

At the beginning of the fall quarter of 1929–30, a battery of tests was administered. These tests in order of their administrations were the Forms A of the author's five tests, Form A of the Iowa Chemistry Test, the Otis Self-administering Test of Mental Ability, and the Whipple High-school and College Reading Test. These tests were administered under as nearly normal and uniform class conditions as possible. The students were also asked to supply on a special questionnaire blank data on their personal histories.

At the end of the term another battery of tests was administered. These tests included Forms B of the investigator's five tests, Form B of the Iowa Chemistry Training Test, and the Holley Sentence Vocabulary Test. The conditions which existed during the administration of these tests were made as nearly as possible identical with those which obtained when the tests of the first battery were administered.

The data from both batteries of tests were given an elaborate statistical treatment which included—

1. A study of individual differences as measured by student performance on the various tests employed. Computations were made from the distribution of the scores on all the tests; of the mean and the median, as measures of central tendency; of the quartile deviation (Q), the 75 percentile (Q_3), the standard deviation, or sigma (S.D.), and the coefficient of variability (V), as measures of dispersion, or variability; and of the S.E. of the average.

2. A study of achievement in general chemistry as related to performance in other tests. This study included computations of coefficients of correlation between the scores of the students on the various tests; and a series of partial correlations involving groups of three and four of the factors tested.

3. A study of achievement in general chemistry as influenced by other factors concerning which data were supplied on the special questionnaire blank. These factors included the sex of the student, the size of high school from which he or she was graduated, the type of school in which he or she learned to read, the influence of the science studied in the high school, and of chemistry when studied as an elective or a required subject.

Conclusions.—1. "The average student reads expositive chemical literature with an efficiency of not greater than 55 per cent"; and general literature with an efficiency not to exceed 44.7 per cent. "Even the superior students have great difficulty in stating the central thought or main theme of the reading selections found in chemistry textbooks."

2. "In his reading of directions in the study of chemistry, the best student . . . is probably at least 2.8 times as efficient as the poorest student."

3. "The average student at the beginning of his study of college chemistry would probably know not more than 44.5 per cent of the technical words met in a typical reading selection from a chemistry textbook"; and probably not more than 64 per cent of the non-technical words.

4. "The ability of the average student of this group to react to the specific fact items in reading expositive chemical literature appears to decrease during the first quarter of study of college chemistry, while his ability to select the central thought or main theme of the selections read seems to increase."

5. The relationships are marked between (1) achievement in chemistry and the ability to read chemical literature; (2) achievement in chemistry and I.Q.; (3) achievement in chemistry and ability to solve a chemical laboratory problem; (4) achievement in chemistry and knowledge of technical words; (5) the abilities measured by the investigator's special tests and general word knowledge; and (6) the abilities measured in the investigator's special tests and I.Q.

6. The relationships are low between (1) achievement in chemistry and general reading ability; (2) achievement in chemistry and general word knowledge; (3) achievement in chemistry and ability to read for directions; (4) teachers' marks and general word knowledge; (5) teachers' marks and general reading ability; and (6) teachers' marks and I.Q.

7. ". . . the average student in learning chemistry probably performs with an efficiency of not to exceed 51 per cent."

8. "There is an extremely wide range of ability of students to learn chemistry . . ."

9. "The average student would probably have great difficulty in solving a chemistry laboratory problem," and "considerable difficulty in applying mathematical principles to the solutions of problems in college chemistry."

10. "The chemistry achievement level of the group . . . practically doubled during 12 weeks' instruction in the first quarter general chemistry in college."

11. "A study of the results of partial correlation indicated that, of all measures employed in this study which might be used for predicting probable success in the study of college chemistry, the battery of special tests is most efficient."

STUDY NO. 254

Important Abilities and Knowledges for Teachers of Secondary-school Physical Science in the Use of Apparatus, Materials, and Tools for Laboratory, Demonstration, and Shop

By Guybert Phillips Cahoon*

UNIT I

Problem.—"To determine important abilities and knowledge in the use of apparatus, materials, and tools for lab-

* Unpublished dissertation for the degree of Doctor of Education, University of California, 1936.

oratory, demonstration, and shop, needed by teachers of secondary-school physical science for working effectively with boys and girls."

Method.—The teachers of science and the student-teachers in the University of California High School were asked to record "the different specific things which they actually did or which it would be desirable for teachers of physical science to be able to do." The list thus secured was supplemented with similar items from the investigator's analysis of a number of textbooks of physics, chemistry, and general science, and of supplementary books. A final list of 325 specific items resulted. This list was submitted to a group of about fifty teachers of physical science and about fifty "supervisors or directors of science in public school systems or in charge of the training of physical science teachers in universities or other teacher-training institutions." These teachers and supervisors were selected from the membership of the National Association for Research in Science Teaching, the faculties of the 30 schools engaged in the Progressive Education Association Experiment, the membership of the American Association of Science Teachers, the authors of articles appearing in recent issues of *Science Education*, and *School Science and Mathematics*, and outstanding teachers and supervisors known to the writer or his associates. These teachers and supervisors were asked to submit additional items to the list, which they did to the number of only 14. They were requested to check each item as "Very Important," "Fairly Important," "Relatively Unimportant," "Unnecessary," and "Uncertain." Check lists returned by 40 supervisors and 40 teachers were compared. Since the two groups agreed "rather closely as to the importance of the various items," the 80 evaluations were combined. Judgments as "Very Important," "Fairly Important," "Relatively Unimportant," and "Unnecessary," were weighted respectively 3, 2, 1, and 0. Checks in the "Uncertain" column were disregarded. The respective

numbers of evaluators who indicated each item as "Very Important," "Fairly Important," and "Relatively Unimportant" were multiplied by the weighted values corresponding to these designations to get a "weighted score" for each of these three judgments or designations. The three weighted scores for each item were then added to get a "total weighted score" for that item.

Findings.—"Nearly all of the 325 items were judged by half or more of the 80 supervisors and teachers as very important or fairly important for teachers of any physical science to be able to do . . . About two-thirds of the items were given one or the other of these two highest designations by 75 per cent or more of the supervisors and teachers in the two highest columns."

A list of the abilities follows:

ABILITIES FOR TEACHERS OF PHYSICAL SCIENCE ARRANGED IN DESCENDING ORDER OF IMPORTANCE AS JUDGED BY EIGHTY SUPERVISORS AND TEACHERS OF SCIENCE[1]

Neutralize acids and bases (as when spilled)
Operate a fire extinguisher
Distill water
Light bunsen burner to prevent shooting back
Make extension cord with socket and plug
Connect voltmeter into a circuit
Read and adjust a mercury barometer
Connect devices in series or parallel
Adjust and repair bunsen burner
Read a hydrometer
Remove glass stoppers which stick
Read and adjust an aneroid barometer
Set up electrolysis of water apparatus
Work with sodium, potassium, phosphorus
Test and replace fuses
Operate and adjust a projection lantern

[1] Because of space limitations only the 224 abilities evaluated as "Very Important" or "Fairly Important" by three-fourths or more of the 80 investigators are here included.

Repair motion picture film
Arrange and store chemicals
Make bends in small glass tubing
Read weather maps
Treat acid and alkali burns
Read a watt-hour meter
Clean substances with least explosion danger
Care for and store explosives
Connect dry cells for maximum current, volts
Connect wires together
Construct simple mercury barometer
Distinguish + from − on dry cell by inspection
Strike tuning forks
Measures focal lengths of lenses
Treat minor cuts and wounds
Read gas, water, and electric meters
Read and attach a pressure gauge
Operate and adjust a motion picture projector
Test to determine + or − terminal of a dry cell or storage battery
Use tape (friction or electrician's)
Set up a prism and light source to show a spectrum dispersion
Use a tourniquet
Clean lenses
Test a bar to determine if magnetized
Cut off glass tubing of small diameter
Test to determine if a circuit is AC or DC
Handle and show the properties of dry ice
Treat burns from fire, steam, etc.
Predict general weather conditions for a day or two in advance from weather maps
Make a simple storage cell
Get acids out of carboys
Disinfect wounds
Care for a vacuum pump
Make a wet-and-dry-bulb hygrometer
Use various instruments usually included in elementary weather recording, as anemometer, rain gauge, barometer, etc.
Install and connect various types of electrical switches, plugs, sockets, etc.
Store and arrange magnets in laboratory
Measure noise and sound
Test the electrical condition of a dry cell
Connect a storage battery to a charger

Use a battery charger or rectifier
Determine the size of a wire (using wire gauge)
Test storage battery for "charge" or "discharge"
Select the proper kind and size of wire for different common uses—as bell wire, resistances, house wiring, etc.
Set up demonstrations of osmosis
Use such tools as pipe- and monkey-wrenches
Clean glass
Replace fuse links in renewable fuses
Make solutions for cleaning glassware
Use a glass-cutter
Soften hard water
Use and care for microscopes
Make normal and molar solutions
Clean the commutator of a motor or generator
Use metal-cutting shears
Connect a relay into a simple electric circuit
Make and operate simple telegraph sounder
Read and use a micrometer caliper
Give treatment for shock and fainting
Improvise a push-button
Remove common stains of various kinds (ink, grease, etc.)
Use a vise
Make and use a "Cartesian diver"
Give artificial respiration
Make and use simple photometers (as shadow, grease-spot, etc.)
Make and use pin-hole camera
Remove foreign substances from eyes
Clean and adjust the make-and-break points on an induction coil
Construct simple hydrometers
Set up a light source having parallel (or nearly parallel) rays
Operate and use a photo-electric cell
Do simple blueprinting
Use glue
Make and use a manometer (for measuring pressures)
Replace gold leaf (or aluminum leaf) on an electroscope
Test the relative conductivity (or ionization) of solutions
Seal a wire into a glass tube or bulb
Make or improvise a screen for lantern or motion picture projection
Care for a lead storage battery
Refill a motor-driven vacuum pump with oil
Make large charts and diagrams (for classroom use)

Make and use a Wheatstone bridge
Do copper electroplating
Read and use a foot-candle meter
Make low-temperature mixtures
Make and read a model vernier
Operate and adjust a static machine (revolving plate type)
Determine which side of an electric circuit is "grounded"
Stop a hemorrhage
Make and use a lamp-bank resistance
Charge a 6-volt battery from a 110-volt DC line
Treat nose-bleed
Set up a model of a hot-water or a steam-heating system
Replace washers in water faucets
Clean copper, brass and other metals
Take good pictures (outdoor and indoor) with a camera
Develop and print pictures
Test for common minerals
Connect a magneto to obtain electrical current
"Tin" a soldering iron
Do simple glass blowing
Set up, adjust, and read a spectroscope
Make crystals "grow"
Change the connections of a series-wound generator to a shunt-wound, and *vice versa*.
Adjust and repair bells and buzzers
Make a sterilized dressing
Make "bridges" of adhesive tape for temporary treatment of a cut
Set a maximum-minimum thermometer
Operate Geissler tubes
Demonstrate optical illusions
Build a simple one-tube or two-tube radio set
"Fix up" a dark room for photo developing and printing
Use a clinical thermometer to take a person's temperature
Make "smoke" for demonstrations
Regulate a thermostat
Treat for poisoning of various kinds
Read blueprints
Make up and use a first-aid packet
Use a blast burner (air and gas)
Prevent "bumping" in rapid boiling
Make "homemade" slides (non-photographic for lantern projection)
Use a gyroscope

Revive a person who is unconscious
Construct and operate a carbon arc light
Magnetize an unmagnetized bar by pounding it while holding it in the direction of the earth's magnetic field
Connect wires to the terminals of a lead storage battery having no binding posts (as auto battery)
Etch glass
Read and use contour or topographical maps
Read charts showing the magnetic variation over the earth (or a portion of the earth)
Improvise a substitute for a commercial fuse
Construct a model of Hero's fountain
Cut off glass bottles or glass tubing of large diameter by means of a hot wire
Reverse direction of an electric motor or generator
Clean mercury
Use and work with liquid air
Make a model of a pump from lamp chimney and rubber stoppers
Use a hack-saw
Construct and operate a simple crystal (radio) set
Use an oilstone
Use a speed counter
Adjust and operate a micro-projector
Arrange two parallel wires conducting electricity so that they will be attracted or repelled
Change a bell or buzzer to operate as a sounder
Refill a fire-extinguisher
Use a Kipps generator
Make a gold-leaf electroscope
Make bulletin boards
Sharpen wood chisels, plane blades, knives, etc.
Write on glass
Carry and store (for a few hours) liquid air
Use an aspirator
Make electrical condensers and Leyden jars
Make an induction coil
Make and use a gravity cell or a Daniel cell
Use a simple planetarium
Use a hectograph
Remagnetize weak magnets
Make antifreeze solutions
Take apart and adjust and use wood planes (jack- and block-planes)

Make a model or demonstration of the important features of common automobile ignition systems

Clean, soften, and care for paint brushes

Distinguish between a ripsaw and a crosscut saw, and properly use each

Use a photo-electric cell for determining illumination, or light intensity

Demonstrate that certain substances other than iron and steel are attracted by magnets

Construct an amateur telescope

Construct a simple electric buzzer

Set up an amateur weather station

Adjust and repair a static machine

Operate an *x*-ray tube

Construct a simple telegraph sounder

Fill toy balloons with hydrogen

File or grind a screw driver

Make a simple thermostat

Demonstrate some of the effects of ultraviolet light

Bore a hole in a piece of glass

Make blueprints of magnetic fields

Do nickle electroplating

Make and give an emetic

Demonstrate that certain substances are repelled by a magnet

Do elementary woodworking

Make a dipping needle

Make Y-tubes and T-tubes of glass or metal tubing

Distil a small amount of crude oil

Set up apparatus to make visible Brownian Movements

Make an "iceless refrigerator" (cooling effect of evaporation)

Make solutions of different colors by the use of chemicals

Use a Crooke's tube (cathode rays)

Demagnetize anything which has become magnetized

Solder with copper and brass

Connect up intercommunicating telephones

Make and use a color-mixer for colored lights

Replace and repair the element in an electric flatiron, heating pad, etc.

Connect up three-way switches (so that a light can be controlled from either of two switches)

Mix and use paint, shellac, varnish, enamels, etc.

Make an electrophorus

Make a photographic lantern slide

Operate a thermo-graph (recording thermometer)

Connect up a thermostat to bells, lights, or motors

Use clamps—as cabinet makers' and C-clamps
Mend broken glass with cement
Make a multipurpose ammeter-voltmeter from a galvanometer and resistances
Make models of the structure of atoms and molecules
Test for the effectiveness of insulation
Make a simple microphone from carbon rods or other common materials
Use a fluoroscope
Draw in perspective
Use a miter box and make miter joints
Demonstrate the use of lightning rods

UNIT II

Problem.—To determine to what extent beginning teachers of physical science possess the abilities and knowledges determined in Unit I.

Method.—The 224 skills and abilities judged to be most important in Unit I were made into a Check List of Performance and submitted to 30 prospective teachers and 30 experienced teachers of physical science, each of whom had had, as teaching majors, one or more of the subjects of chemistry, physics, or general science. These teachers were asked to indicate for each item whether or not they could perform the task or skill indicated by it.

A battery of five performance tests was next designed to test the possession of important abilities in using apparatus, materials, and tools. "For each performance test the necessary (and some unnecessary) apparatus, materials, and tools were directly available in one place on a laboratory table. A special scoring key was devised by first performing the problem and listing for each step the procedure which was considered good technique and practice. These scoring keys were checked by having three selected teachers and supervisors observe a number of other experienced teachers 'perform' the problems. On the basis of this preliminary tryout and some experience in using the tests, the problems and scoring keys were modified to their final form. These tests, containing

each from 20 to 46 specific items of performance, were then administered to 20 experienced and 20 inexperienced teachers of physical science."

Because of the difficulty of constructing, administering, and scoring such tests of performance, the use of this type of test was deemed impractical. Several experiments were therefore conducted in which various types of tests of performance were tried out with groups of experienced and inexperienced teachers of physical science. As a result of these experiments a Background Inventory for Physical Science Teachers of 90 items was constructed by combining an information test of the master-list type with a check list of performance. This test was administered to 231 beginning or prospective teachers of physical science, and the results were analyzed.

Findings.—1. With respect to the Check List of Performance, half or more of the inexperienced teachers admitted that they had not performed 70 per cent, and half or more of the experienced teachers admitted that they had not performed 43 per cent, of the abilities listed.

2. "The data from the five performance tests indicated that both the inexperienced and the experienced teachers of this group received scores which were only about half of the total possible score value," and that only "about half of each group performed properly half or less of the specific problems."

3. The results with the Background Inventory for Physical Science Teachers showed that half or fewer than half the beginning teachers were able to respond correctly to as many as half the items on any part of the test.

UNIT III

Problem.—"To plan a program in which teachers of secondary-school physical science may have experiences which will help them to gain needed knowledge and abilities in the use of apparatus, materials, and tools."

Method.—On the basis of the results of the preceding two units and with the use of the various measuring devices and lists of necessary skills, a plan was devised "so as to offer opportunity for students to get experience in the use of fundamental techniques needed in working with apparatus, materials, and tools, and in the using and making of demonstration and laboratory apparatus needed in the teaching of secondary-school physical science. The experiences in techniques in this plan include problems in simple glassworking, metalworking, woodworking, electrical techniques, chemical techniques, using of visual aids, and safety and first aid. These techniques are then used in connection with carrying out the problems in the using and making of demonstration and laboratory apparatus. Experience in using and making apparatus involves problems in assembling and constructing apparatus grouped under the headings of gases and liquids, heat, electrical circuits and devices, light and optical instruments, radio, radiations and photo-electricity, and purchasing and storing supplies."

STUDY NO. 255

Curriculum Analysis as a Basis for Determining Science Rooms, Service, and Furnishings in Teachers Colleges

By Harry A. Cunningham*

Problem.—To determine what laboratory activities, equipment, services, and facilities should be provided in the training of teachers of science in the intermediate grades.

Method.—An analysis was made (1) of 14 courses of study in science for Grades IV, V, and VI, all of which are ranked

* *Science Education*, XX (October, 1936), 151–156. This report is a unit of the investigator's dissertation for the degree of Doctor of Philosophy, Teachers College, Columbia University; the entire dissertation will be published later.

in the upper quartile by the Bureau of Curriculum Research, Teachers College, Columbia University; (2) of nine books and laboratory manuals written for teachers of elementary science; (3) of 25 books written specifically for pupils studying science in the fourth, fifth, and sixth grades; and (4) of 39 books and laboratory manuals. These latter had not been written specifically for use by either pupils or teachers in the intermediate grades, but "were either referred to in the courses of study analyzed, or were judged by the investigator to give, in more detail, descriptions of the laboratory activities together with the specialized materials needed, indicated as necessary in the attainment of an understanding of the principles and generalizations discovered as objectives."

Two kinds of statements were obtained: (1) "a list of statements of relationships—generalizations—which are used as objectives toward which the teaching should be directed consciously by the teachers but concerning which the pupils themselves are to be, for the present, unconscious; and (2) statements . . . indicating the activities used in the development of the objectives listed or used in making the important words in the generalizations more meaningful, in the performance of which some sort of specialized material facilities are indicated." All statements were carded together with the number of the course of study or book, and the page where the statement appeared.

The statements were analyzed into four classifications: (1) "statements of generalizations . . . classified according to the type of interaction indicated"; (2) "generalizations stated as words or phrases"; (3) equipment or supplies used in the activities; and (4) "the activities carried on with the materials used." These four sets of cards were so inter-referenced that by starting with any card in any of the four groups all the related objectives, activities, products of the activities, and materials could readily be located in the other three categories.

Findings and Conclusions.—1. The analysis revealed 2,337 different items of either equipment or supplies, which were

TABLE IC

FREQUENCY OF MENTION OF IMPORTANT ITEMS OF EQUIPMENT AND SUPPLIES

Article	Number of times mentioned	Article	Number of times mentioned
Animals	100	Leaves	75
Aquaria	112	Magnets	75
Bacteria	75	Pans	100
Bottles	200	Paper	125
Boxes	75	Pictures	175
Bunsen burner	250	Plants	175
Candles	125	Ring stand	100
Cardboard	87	Rubber stoppers	150
Charts	75	Rubber tubing	87
Cloth	100	Salt	75
Corks	75	Sand	75
Dishes	100	Seeds	100
Dry cells	75	Soil	175
Plates of glass	75	Test tubes	175
Glass tubing	225	Thermometers	100
Glass tumblers	100	Water	400
Jars	75	Wire	75
Lantern slides	75	Wood	175

TABLE C

FREQUENCY OF MENTION OF IMPORTANT ACTIVITIES

Activity	Number of times mentioned	Activity	Number of times mentioned
Collecting	75	Measuring	50
Demonstrating	25	Observing	50
Examining	75	Planting	100
Growing	50	Showing	150
Keeping (caring for)	100	Testing	100
Making	800	Using	800

mentioned 24,000 times; and 277 separate activities, mentioned 5,400 times. The items of equipment and supplies and the activities most frequently mentioned in the materials analyzed are shown in Tables IC and C.

2. In planning the science rooms, service and furnishings needed in the training of teachers of science in the intermediate grades, "consideration must be given to the provision of electrical outlets, gas, lighting, hot and cold water, [and] abundant table space with various specialized features; to storage and display facilities; and to sufficient floor space to provide for the extra space taken up by these specialized furnishings."[1]

[1] In an unpublished study* of the rooms, service, and furnishings used in 17 teachers colleges in the training of intermediate-grade teachers in science, Cunningham arrived at the following findings and conclusions:

1. There is little or no uniformity in the names of courses given in science for the training of intermediate-grade teachers in the schools studied.

2. Many teachers colleges provide little or no facilities for training intermediate-grade teachers in physical science.

3. Aside from the rooms that are used for classroom work, either recitation or laboratory, there is not much uniformity as to rooms such as growing rooms, animal rooms or animal houses, preparation rooms, museums, etc., which are used in the training of intermediate-grade teachers.

4. There is not much uniformity in the type of room used for class work or laboratory work.

5. These rooms in which class work and laboratory work are carried on, may be classified into five types: (a) recitation; (b) recitation plus laboratory; (c) recitation or laboratory; (d) laboratory; (e) lecture demonstration.

6. None provide, in a satisfactory manner, for independent supplementary project work which is now being emphasized and in which many of the teachers of these teachers' courses are interested.

7. In many cases teachers colleges do not have adequate furnishings in the way of storage space for the materials they do have.

* Harry A. Cunningham, The Material Facilities Used in the Training of Intermediate-grade Teachers in Science. Unpublished Study.

3. "There is need in teachers colleges for attention to the selection of the laboratory activities needed in the professional training of intermediate-grade teachers; for more attention to the necessary equipment and supplies needed to make these activities possible; and finally for more attention to the rooms, service, and furnishings necessary for the use of the equipment and supplies needed in the laboratory activities decided upon."

STUDY NO. 256

Measurement of Some of the Outcomes of Laboratory Work in College Physics

By Henry Ward Duel*

UNIT I

Problem.—To determine whether students gain a better "knowledge and understanding of the fundamental facts and basic laws of *mechanics*" when they have two hours of laboratory work per week for one quarter than when they have no laboratory work accompanying the classwork.

Method.—The three units of this investigation were carried on during the years 1930–34, with a total of 595 beginners in the Department of Physics, mostly Freshmen and Sophomores, at the University of Minnesota.

In Unit I comparisons were made between four representative groups of students numbering respectively 21, 45, 36, and

* Dissertation for the degree of Doctor of Philosophy, University of Minnesota, 1936. The second chapter of this dissertation, only slightly modified, is published under the title, "Measurable Outcomes of Laboratory Work in Science: a Review of Experimental Investigations," in *School Science and Mathematics*, XXXVII (October, 1937), 795–810; a brief summary of the experimental portions of the dissertation is inserted near the end of this published article. A brief abstract of this study appears under the original title in *Bulletin of the American Association of Collegiate Registrars*, XII (April, 1937), 202–206.

21 pairs each, paired both on the basis of a composite score constructed from scores on the Minnesota College Aptitude Test, the Minnesota Mathematical Abilities Test, and the Stanford Test of Scientific Aptitudes; and also on the bases of sex, major interests, and completion of a course in high-school physics. Comparisons were also made of three pairs of groups of these same students representing respectively high, medium, and low ability, and composed of respectively 14 and 11 cases, 20 and 10 cases, and 10 and 19 cases. These groups were equated on the basis of composite scores on a battery of tests similar to those used for the groups of paired students. Computations of critical ratios indicated that the groups were comparable. Results were measured with certain of these groups in terms of scores on a final examination and a final average of quiz marks; and with others in terms of differences in initial and final test scores.

The reliability of the differences was determined by computations of critical ratios, (difference in means divided by the S.E. of this difference) and variability of achievement (difference in S.D.'s divided by the S.D. of this difference).

Findings.—1. "None of the comparisons showed a statistically significant difference in mean achievement between the matched groups. The small differences which appeared were not consistent; they favored the no-laboratory group more than the laboratory group, but the variations in direction were well within the limits of chance fluctuations."

2. "When the pairs were considered individually, the differences within the separate pairs showed no decisive trend in favor of either group . . ."

UNIT II

Problem.—To determine whether students who have two hours of laboratory work per week achieve a development of scientific aptitudes superior to that achieved by other students who have no laboratory work.

Method.—Comparisons were made between four representative groups of students, numbering respectively 24, 10, 25, and 48 pairs, paired on the same bases as those used for pairing in Unit I. Similar comparisons were made between three pairs of groups representing respectively high, medium, and low ability and composed of respectively 43 and 30 cases, 22 and 14 cases, and 49 and 30 cases, and also between five pairs of larger groups, representing respectively the three levels of ability and selected respectively from the first, third, and fifth groups, and from the second, fourth, and sixth groups. All these equivalent groups were equated on the basis of initial scores on the Stanford Scientific Aptitudes Test. Gains were computed on the basis of initial and final scores on this test. The reliability of the differences and the variability of achievement were determined by statistical procedures similar to those employed in Unit I.

Findings.—"The comparisons showed no significant differences between the laboratory and the no-laboratory groups with respect to score gains on the Stanford Scientific Aptitudes Test, either in the means or in the S.D.'s."

UNIT III

Problem.—To determine whether students who have two laboratory periods per week gain with respect to manipulative skills and a knowledge of laboratory techniques more than do those who have no laboratory work.[1]

Method.—"Students who did two hours per week of laboratory work in *mechanics* were compared with students who did no laboratory work in *mechanics* with respect to their achievement in subsequent courses in *heat* and *electricity*." Comparisons were made between paired groups numbering respectively 27 and 24 pairs equated on the basis of composite scores as in the preceding units.

[1] Compare this study with that of Horton, *Investigations in the Teaching of Science*, Vol. II, pp. 302–311.

Findings.—". . . there were no significant differences in achievement between the *mechanics* laboratory and no-laboratory groups; it is obvious that, on the average, the students who did no laboratory work in *mechanics* achieved as much in *heat* and *electricity* laboratory courses as those students who did two hours of laboratory work per week in *mechanics*."

Conclusions.—1. "Students in *mechanics* who do no laboratory work will gain, on the average, as much knowledge and understanding of the fundamental facts and laws of *mechanics* as those students who do two hours of laboratory work per week for a period of one quarter; there will be very little difference between the two groups with respect to variability in achievement."

2. "The average student in *mechanics*, over a period of one quarter, will improve a small but statistically reliable amount in scientific aptitude, as this aptitude is measured by the Stanford Scientific Aptitudes Test; two hours of laboratory work per week will have no significant effect upon the amount of this improvement."

3. "On the average, students who take the laboratory work in *mechanics* will not acquire sufficient manipulative skill and knowledge of laboratory techniques to affect noticeably their achievement in subsequent laboratory courses in *heat* and *electricity*, as this achievement is measured in this investigation; if they do gain skill in the manipulation of apparatus and a knowledge of laboratory techniques, these manipulative skills and techniques will be of negligible value outside of the *mechanics* laboratory."

STUDY NO. 257

The Lecture-demonstration and Individual Laboratory Methods Compared: (1) The Literature; (2) the Distribution of Time; and (3) Experimental[1]

By Virgil Francis Payne*

Problem.—To determine the relative values of class demonstration and individual laboratory instruction in first-year college chemistry classes.

Method.—Two hundred ninety-nine students in 12 sections enrolled in four colleges and taught by five instructors, provided six experimental groups of two paired sections each. The groups, but not the individual students within the groups, were paired on three bases: scores on the Iowa Placement Examination (Chemistry Aptitude), scores on the Powers' General Chemistry Examination; and I.Q.'s in all cases in which these were available. The scores on the tests were given arbitrary weightings by the investigator, who weighted most heavily the scores on the Iowa Placement Examination (Chemistry Aptitude).

"One section of each group was taught during the first part of the year, generally a semester, by class demonstration with no individual laboratory work during this introductory work, while the paired section was taught throughout the year's

[1] See also studies comparing these methods by Phillips, Cunningham, Hunter, Cooprider, and Kiebler and Woody, *Investigations in the Teaching of Science*, Vol. I, pp. 46–48, 48–51 and 100–103, 61–63, 72–75 and 90–93, and 85–90, respectively; and by Johnson, Dyer, Carpenter, Pruitt, Anibal, Knox, and Horton, Vol. II, pp. 189–191, 227–230, 284–289, 292–295, 295–299, and 302–311, respectively.

* Doctor's dissertation, University of Kentucky, 1931. This digest is made from a report of this study in *Journal of Chemical Education*, IX (May, June, and July, 1932), 932–937, 1097–1102 and 1277–1294. Only the third unit, that dealing with the investigational phases of the problem, is here presented.

work by the more commonly used individual laboratory method. After the introductory period by class demonstration, . . . this section of students joined the other section in study by the individual laboratory."

Attainment of the paired groups was measured by scores on three standardized tests administered at intervals; the Iowa Placement Examination (Chemistry Training); the Powers' General Chemistry Test, and the Rich's Chemistry Test. Twenty-four other tests were constructed by the investigator, which "could be scored as nearly objectively as seemed reasonable." The reliability of these tests, by the method of chance-halves, corrected for the whole test by the Spearman-Brown Formula, was found to be 0.74. Their validity, as determined from correlations of scores on Tests I–IX of this group with scores on the Iowa Placement Examination (Chemistry Training), and with teachers' marks, were respectively 0.66 and 0.68.

Comparisons of the achievement of the six pairs of groups, by the two laboratory methods, the demonstration and the individual, were made for the entire groups and for students in the upper and lower halves of the groups, for men and women, and for men and women in the upper and lower halves of the groups, on several bases: (1) the percentile ranks of paired students, based on the scores on the various measures of attainment; (2) the relative numbers of pairs of students furnishing data on the investigator's tests, on the standardized tests, and on all marks combined, favorable either to the demonstration method or the individual laboratory method; (3) the percentages of students whose ranks on the semester tests exceeded their predicted ranks or "expectation ranks" (these expectation ranks for each student in a paired group were obtained by combining the ranks of his scores of the three pre-tests, assigned in relation to the scores of all the other members of his paired group on these same tests); (4) the gains on the author's tests, determined in mean Sigma scores, with allowances made for differences in the Sigma scores

on the pre-tests (thus the difference in Sigmas of each paired group based on the composite pre-test scores was added algebraically to the difference in Sigmas of the same group on the attainment tests); and (5) computation of "critical ratios" determined (on the results of the standardized tests) by both the short[1] and the long formula[2] from Sigma differences, with corrections made as has just been explained, for differences "in aptitude on the sections compared as measured by the pre-tests."

The preferences of the men and women students for the two methods were also taken on the bases of which method was more interesting and which method enabled the pupil in his own opinion to learn more, to understand better, or to remember better.

Findings.—1. On the basis of percentile ranks, "when all the measures of all the groups are summarized by semesters, no marked differences are seen in the upper halves of the groups, but in the lower halves and in the whole group the demonstration sections are favored during both semesters. The difference favoring the demonstration sections is more marked in the second semester than during the first semester. This same variation of results between the upper and lower halves of the groups exists if we summarize by groups instead of by separate measures within the groups."

2. On the basis of percentages of pairs of students who made higher scores on the investigator's examinations, "in the upper half of these groups nine of these examinations furnish data favorable to demonstration to five favorable to laboratory.

[1] $\text{P.E.}\ (\text{Diff.}_m) = .6745\sqrt{\frac{\text{S.D.}_1^2}{N_1} + \frac{\text{S.D.}_2^2}{N_2}}.$

[2] $\text{P.E.}\ (\text{Diff.}_m) = .6745\sqrt{\frac{\text{S.D.}_1^2}{N_1} + \frac{\text{S.D.}_2^2}{N_2} - 2r_{1,2}\frac{\text{S.D.}_1\text{S.D.}_2}{\sqrt{N_1N_2}}}.$ (The coefficient of reliability of the tests was substituted for the more usual r based on individual scores because individuals were not paired.)

In the lower half of the group the corresponding ratio is 13:1, and in the groups as a whole, 11:3."

3. On the basis of percentages of pairs of students who made higher scores on the standardized examinations, "the demonstration method is favored throughout in the upper half, 11:4; in the lower half, 14:2; in the whole of the groups, 12:3."

4. On the basis of the percentage of pairs of students who made higher scores on all measures combined, "as much of the data favors one method as the other in the upper halves of the groups. However, in the lower halves, the demonstration method is favored by a ratio of 13:4; and in the whole group by a ratio of 12:5."

5. On the basis of performance as compared with prediction, "four of the six groups furnish data favorable to the individual laboratory method." Two groups furnish data "entirely favorable to the demonstration method. The other four groups furnish two measures favorable to the demonstration method and two measures favorable to the individual laboratory method . . ."

6. On the basis of a comparison of the work of the men and the women, "in only four of 24 comparisons do the laboratory-section students exceed the record of the demonstration-section students. These are the upper-half laboratory men for the first half of the second semester and the upper-half and lower-half and whole-group laboratory women for the first half of the first semester. In 11 of the 12 divisions of this table, there are indications that the women have used the laboratory method relatively better than the men."

7. On the basis of Sigma gains, "taking all the groups as a unit, the demonstration method is favored by the data from the men by 0.41 Sigma, women by 0.25 Sigma, and both combined by 0.31 Sigma. These data again indicate that the men have not used the laboratory relatively to as good an advantage as have the women."

8. On the basis of critical ratios, "by the use of the short formula, only one critical ratio greater than 3.00 is obtained. This is . . . favorable to the demonstration section. By the longer formula five critical ratios above 3.00, and two more, only slightly less, are obtained, all favorable to the work of the demonstration sections. Only three of the 18 measures favor the work of the laboratory sections."

9. "The . . . sigma index (mean Sigma on tests minus Sigma predicted on pre-test) for the demonstration students has improved 0.23 while that of the laboratory students has shown a loss of 0.12."

10. "Only a slightly larger percentage of those choosing the demonstration method list as a reason their belief that they learn more. Distinctly larger percentages of reasons for choice of the laboratory method are that the method is more interesting and that the individuals remember better."

11. "Of all the students beginning the course by the individual laboratory method, 68.6 per cent would prefer that method if they were beginning the course again. The choice of 77.1 per cent of all the students beginning the course by the lecture-demonstration is that same method."

Conclusions.—1. ". . . these students made better progress, . . . when introduced to the study of college chemistry by the lecture-demonstration method."

2. ". . . it seems reasonable to conclude that the students of lesser ability profited relatively more by the introduction through lecture-demonstration than did the students of greater ability."

3. ". . . there is some reason to believe that the women students have made relatively better use of the individual laboratory work than have the men students."

4. "There are indications that the later work by the individual laboratory method is strengthened by the lecture-demonstration introduction to the course."

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